The
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YEAR BOOK
1926

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The Chemists' Year Book

1926

THE

CHEMISTS'
YEAR BOOK

1926

EDITED BY
F. W. ATACK

M.Sc. Tech., D.Sc. (Manc.), B.Sc. (Lond.).
Fellow of the Institute of Chemistry.

PREFACE TO THE ELEVENTH EDITION (1926).

The present edition contains a new section on "Lubricants" by H. Moore, M.Sc. Tech. The American methods included in the section on "Agricultural Chemistry" have been revised by Arthur L. Prince, M.Sc. General revisions have been made by other contributors to maintain the standard of this publication.

The Editor has again to thank numerous correspondents for valuable suggestions.

THE EDITOR.

34, Cross Street,   Kingston, Ontario,

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December, 1925.

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The Chemists' Year Book

1926

ATOMIC WEIGHTS 1926.

Name.	Symbol.	O = 16.
Aluminium	Al	26.97
Antimony	Sb	121.77
Argon	A	39.91
Arsenic	As	74.96
Barium	Ba	137.37
Bismuth	Bi	209.0
Boron	B	10.82
Bromine	Br	79.92
Cadmium	Cd	112.41
Cæsium	Cs	132.81
Calcium	Ca	40.07
Carbon	C	12.000
Cerium	Ce	140.25
Chlorine	Cl	35.46
Chromium	Cr	52.01
Cobalt	Co	58.94
Columbium (*Niobium*)	Cb	93.1
Copper	Cu	63.57
Dysprosium	Dy	162.52
Erbium	Er	167.7
Europium	Eu	152.0
Fluorine	F	19.0
Gadolinium	Gd	157.3
Gallium	Ga	69.72
Germanium	Ge	72.60
Glucinum (*Beryllium*)	Gl	9.02
Gold	Au	197.2
Helium	He	4.00
Holmium	Ho	163.4
Hydrogen	H	1.008
Indium	In	114.8
Iodine	I	126.93
Iridium	Ir	193.1
Iron	Fe	55.84
Krypton	Kr	82.92
Lanthanum	La	138.90
Lead	Pb	207.20
Lithium	Li	6.94
Lutetium	Lu	175.0
Magnesium	Mg	24.32
Manganese	Mn	54.93

A

Name.	Symbol.	O = 16
Mercury	Hg	200.61
Molybdenum	Mo	96.0
Neodymium	Nd	144.27
Neon	Ne	20.2
Nickel	Ni	58.69
Niton (radium emanation)	Nt	222.0
Nitrogen	N	14.008
Osmium	Os	190.8
Oxygen	O	16.00
Palladium	Pd	106.7
Phosphorus	P	31.03
Platinum	Pt	195.2
Potassium	K	39.10
Praseodymium	Pr	140.92
Radium	Ra	225.95
Rhodium	Rh	102.9
Rubidium	Rb	85.44
Ruthenium	Ru	101.7
Samarium	Sa	150.4
Scandium	Sc	45.1
Selenium	Se	79.2
Silicon	Si	28.06
Silver	Ag	107.88
Sodium	Na	23.00
Strontium	Sr	87.63
Sulphur	S	32.06
Tantalum	Ta	181.5
Tellurium	Te	127.5
Terbium	Tb	159.2
Thallium	Tl	204.39
Thorium	Th	232.15
Thulium	Tm	169.4
Tin	Sn	118.7
Titanium	Ti	48.1
Tungsten	W	184.0
Uranium	U	238.2
Vanadium	V	50.96
Xenon	X	130.2
Ytterbium	Yb	173.6
Yttrium	Yt	88.9
Zinc	Zn	65.38
Zirconium	Zr	91.0

Multiples of the Atomic Weights and their Logarithms.

(Calculated from Atomic Weights, 1923.)

	.1 0.00000	2 .30103	3 .47712	4 .60206	5 .69897	6 .77815	7 .84510	8 .90309	9 .95424	10 1.00000	Log.
Aluminium ......Al	27.0	54.0	81.0	108.0	135.0	162.0	189.0	216.0	243.0	270	1.43136
Antimony ......Sb	120.2	240.4	360.6	480.8	601	721.2	841.4	961.6	1081.8	1202	2.07990
Arsenic ......As	74.96	149.92	224.88	299.84	374.8	449.76	524.72	599.58	674.64	749.6	1.87483
Barium ......Ba	137.37	274.74	412.11	549.48	686.85	824.22	961.59	1098.96	1236.33	1373.7	2.13789
Bismuth ......Bi	209	418	627	836	1045	1254	1463	1672	1881	2090	2.32015
Boron ......B	10.9	21.8	32.7	43.6	54.5	65.4	76.3	87.2	98.1	109	1.03743
Bromine ......Br	79.92	159.84	239.76	319.68	399.6	479.52	559.44	639.36	719.28	799.2	1.90266
Cadmium ......Cd	112.4	224.8	337.2	449.6	562	674.4	786.8	899.2	1011.6	1124	2.05077
Caesium ......Cs	132.81	265.62	398.43	531.24	664.05	796.86	929.67	1062.48	1195.29	1328.1	2.12323
Calcium ......Ca	40.07	80.14	120.21	160.28	200.35	240.42	280.49	320.56	360.63	400.7	1.60282
Carbon C	12.005	24.010	36.015	48.020	60.025	72.030	84.035	96.040	108.045	120.05	1.07936
Cerium ......Ce	140.25	280.5	420.75	561	701.25	841.5	981.75	1122	1262.25	1402.5	2.14690
Chlorine Cl	35.46	70.92	106.38	141.84	177.30	212.76	248.22	283 68	319.14	354 6	1.54974
Chromium ......Cr	52	104	156	208	260	312	364	416	468	520	1.71600
Cobalt ......Co	58.97	117.94	176.91	235.88	294.85	353.82	412.79	471.76	530.73	589.7	1.77063
Columbium ......Cb	93.1	186.2	279.3	372.4	465.5	558.6	651.7	744.8	837.9	931.0	1.96895
Copper ......Cu	63.57	127.14	190.71	254.28	317.85	381.42	444.99	508.56	572.13	635.7	1.80325
Erbium ......Er	167.7	335.4	503.1	670.8	838.5	1006.2	1173.9	1341.6	1509.3	1677	1.22453
Fluorine ......F	19	38	57	76	95	114	133	152	171	190	1.27875
Gallium ......Ga	70.1	140.2	210.3	280 4	350.5	420.6	490.7	560.8	630.9	701	1.84572
Germanium ......Ge	72.5	145	217.5	290	362.5	435	507.5	580	662.5	725	1.86034

		1 0.00000	.30103	.47712	.60206	5 .69897	6 .77815	7 .84510	8 .90309	9 .95424	1.00000	Log.
Glucinum	Gl	9.1	18.2	27.3	36.4	45.5	54.5	63.7	72.8	81.9	91.0	0.95904
Gold	Au	197.2	394.4	591.6	788.8	986	1183.2	1380.4	1577.6	1774.8	1972	2.29491
Hydrogen	H	1.008	2.016	3.024	4.032	5.04	6.048	7.056	8.064	9.072	10.08	0.00346
Indium	In	114.8	229.6	344.4	459.2	574	688.8	803.6	918.4	1033.2	1148	2.05994
Iodine	I	126.92	253.84	380.76	507.68	634.6	761.52	888.44	1015.36	1142.28	1269.2	2.10353
Iridium	Ir	193.1	386.2	579.3	772.4	965.5	1158.6	1351.7	1544.8	1737.9	1931	2.28578
Iron	Fe	55.84	111.68	167.52	223.36	279.2	335.04	390.88	446.72	502.56	558.4	1.74695
Lanthanum	La	139	278	417	556	695	834	973	1112	1251	1390	2.14301
Lead	Pb	207.2	414.4	621.6	828.8	1036.0	1243.2	1450.4	1657.6	1864.8	2072	2.31639
Lithium	Li	6.94	13.88	20.82	27.76	34.7	41.64	48.58	55.52	62.46	69.4	0.84136
Magnesium	Mg	24.32	48.64	72.96	97.28	121.6	145.92	170.24	194.56	218.88	243.2	1.38596
Manganese	Mn	54.93	109.86	164.79	219.72	274.65	329.58	384.51	439.44	494.37	549.3	1.73981
Mercury	Hg	200.6	401.2	601.8	802.4	1003	1203.6	1404.2	1604.8	1805.4	2006	2.30233
Molybdenum	Mo	96	192	288	384	480	576	672	768	864	960	1.98227
Nickel	Ni	58.68	117.36	176.04	234.72	293.4	352.08	410.76	469.44	528.12	586.8	1.76849
Nitrogen	N	14.008	28.016	42.024	56.032	70.040	84.048	98.056	112.064	126.072	140.08	1.14638
Osmium	Os	190.9	381.8	572.7	763.6	954.5	1145.4	1336.3	1527.2	1718.1	1909	2.28081
Oxygen	O	16	32	48	64	80	96	112	128	144	160	1.20412
Palladium	Pd	106.7	213.4	320.1	426.8	533.5	640.2	746.9	853.6	960.3	1067	2.02816
Phosphorus	P	31.04	62.08	93.12	124.16	155.20	186.24	217.28	248.32	279.36	310.4	1.49192
Platinum	Pt	195.2	390.4	585.6	780.8	976	1171.2	1366.4	1561.6	1756.8	1952	2.29048
Potassium	K	39.1	78.2	117.3	156.4	195.5	234.6	273.7	312.8	351.9	391	1.59218
Rhodium	Rh	102.9	205.8	308.7	411.6	514.5	617.4	720.3	823.2	926.1	1029	2.01242

	1 0.00000	2 .30103	3 .47712	4 .60206	5 .69897	6 .77815	7 .84510	8 .90309	9 .95424	10 1.00000	Log.
Rubidium ....Rb	85.45	170.9	256.35	341.8	427.25	512.7	598.15	683.6	769.05	854.5	1.93171
Ruthenium ......Ru	101.7	203.4	305.1	406.8	508.5	610.2	711.9	813.6	915.3	1017	2.00732
Samarium ....Sa	150.4	300.8	451.2	601.6	752	902.4	1052.8	1203.2	1353.6	1504	2.17725
Scandium ....Sc	45.1	90.2	135.3	180.4	225.5	264.6	308.7	352.8	396.9	451	1.65418
Selenium ....Se	79.2	158.4	237.6	316.8	396	481.2	561.4	641.6	721.8	792	1.89873
Silicon ....Si	28.1	56.2	84.3	112.4	140.5	168.6	196.7	224.8	252.9	281	1.44871
Silver ....Ag	107.88	215.76	323.64	431.52	539.4	647.28	755.16	863.04	970.92	1078.8	2.03294
Sodium ....Na	23	46	69	92	115	138	161	184	207	230	1.36173
Strontium ......Sr	87.63	175.26	262.89	350.52	438.15	525.78	613.41	701.04	788.67	876.3	1.94265
Sulphur ....S	32.06	64.12	96.18	128.24	160.30	192.36	224.42	256.48	288.54	320.6	1.50596
Tantalum ....Ta	181.5	363	544.5	726	907.5	1089	1270.5	1452	1633.5	1815	2.25888
Tellurium ......Te	127.5	255	382.5	510	637.5	765	892.5	1020	1147.5	1275	2.10551
Thallium ....Tl	204	408	612	816	1020	1224	1428	1632	1836	2040	2.30963
Thorium ....Th	232.15	464.30	696.45	928.60	1160.75	1392.90	1625.05	1857.20	2089.35	2321.5	2.36677
Tin ....Sn	118.7	237.4	356.1	474.8	593.5	712.2	830.9	949.6	1068.3	1187	2.07445
Titanium ....Ti	48.1	96.2	144.3	192.4	240.5	288.6	336.7	384.8	432.9	481	1.68215
Tungsten ....W	184	368	552	736	920	1104	1288	1472	1656	1840	2.26482
Uranium ....U	238.2	476.4	714.6	952.8	1191.0	1429.2	1667.4	1905.6	2143.8	2382	2.37694
Vanadium V	51	102	153	204	255	306	357	408	459	510	1.70757
Ytterbium ......Yb	173.5	347	520.5	694	867.5	1041	1214.5	1388	1561.5	1735	2.23930
Yttrium ....Y	89.33	178.66	267.99	357.32	446.65	535.98	625.31	714.64	803.97	893.3	1.95085
Zinc ....Zn	65.37	130.74	196.11	261.48	326.85	392.22	457.59	522.96	588.33	653.7	1.81538
Zirconium ......Zr	90.6	181.2	271.8	362.4	453	543.6	634.2	724.8	815.4	906	1.95713

	11	12	13	14	15	16	17	18	19	20	Log.
	1.04139	1.07918	1.11394	1.14613	1.17609	1.20412	1.23045	1.25527	1.27875	1.30103	
Carbon C	132.055	144.060	156.065	168.070	180.075	192.080	204.085	216.090	228.095	240.10	1.07936
Chlorine Cl	390.06	425.52	460.98	496.44	531.90	567.36	602.82	638.28	673.74	709.20	1.54974
Hydrogen ......H	11.088	12.096	13.104	14.112	15.12	16.128	17.136	18.144	19.152	20.16	0.00346
Nitrogen ....N	154.088	168.096	182.104	196.112	210.120	224.128	238.136	252.144	266.152	280.16	1.14638
Oxygen ....O	176	192	208	224	240	256	272	288	304	320	1.20412
Silicon ....Si	309.1	337.2	365.3	393.4	421.5	449.6	477.7	505.8	533.9	562	1.44871

	21	22	23	24	25	26	27	28	29	30	Log.
	1.32222	1.34242	1.36173	1.38021	1.39794	1.41497	1.43136	1.44716	1.46240	1.47712	
Carbon C	252.105	264.110	276.115	288.120	300.125	312.130	324.135	336.140	348.145	360.15	1.07936
Hydrogen ......H	21.168	22.176	23.184	24.192	25.2	26.208	27.216	28.224	29.232	30.24	0.00346
Oxygen ....O	336	352	368	384	400	416	432	448	464	480	1.20412

	31	32	33	34	35	36	37	38	39	40	Log.
	1.49136	1.50515	1.51851	1.53148	1.54407	1.55630	1.56820	1.57978	1.59106	1.60206	
Carbon C	372.155	384.160	396.165	408.170	420.175	432.180	444.185	456.190	468.195	480.20	1.07936
Hydrogen ......H	31.248	32.256	33.264	34.272	35.28	36.288	37.296	38.304	39.312	40.32	0.00346

	41	42	43	44	45	46	47	48	49	50	Log.
	1.61278	1.62325	1.63347	1.64345	1.65321	1.66276	1.67210	1.68124	1.69020	1.69897	
Carbon C	492.205	504.210	516.215	528.220	540.225	552.230	564.235	576.240	588.245	600.25	1.07936
Hydrogen ......H	41.328	42.336	43.344	44.352	45.36	46.368	47.376	48.384	49.392	50.4	0.00346

Formula Weights of Certain Radicals and their Multiples.

Radical	Formula	1	2	3	4	5	6	7	8	9	10	Log.
		0.00000	.30103	.47712	.60206	.69897	.77815	.84510	.90309	.95424	1.00000	
Amino	NH_2	16.024	32.048	48.072	64.096	80.120	96.144	112.168	128.192	144.216	160.240	1.20477
Ammonium	NH_4	18.040	36.080	54.120	72.160	90.200	108.240	126.280	144.320	162.360	180.400	1.25624
Carbonate	CO_3	60.00	120.00	180.00	240.00	300.00	360.00	420.00	480.00	540.00	600.00	1.77815
Carbonyl	CO	28.00	56.00	84.00	112.00	140.00	168.00	196.00	224.00	252.00	280.00	1.44716
Carboxyl	$COOH$	45.01	90.02	135.02	180.03	225.04	270.05	315.06	360.06	405.07	450.08	1.65331
Ethyl	C_2H_5	29.04	58.08	87.12	116.16	145.20	174.24	203.28	232.32	261.36	290.40	1.46300
Hydroxyl	OH	17.01	34.02	51.02	68.03	85.04	102.05	119.06	136.06	153.07	170.08	1.23065
Methyl	CH_3	15.02	30.05	45.07	60.10	75.12	90.14	105.17	120.19	135.22	150.24	1.17679
Naphthyl	$C_{10}H_7$	127.06	254.11	381.17	508.22	635.28	762.34	889.39	1016.45	1143.50	1270.56	2.10399
Nitrate	NO_3	62.01	124.02	186.02	248.03	310.04	372.05	434.06	496.06	558.07	620.08	1.79245
Nitro	NO_2	46.01	92.02	138.02	184.03	230.04	276.05	322.06	368.06	414.07	460.08	1.66284
Phenyl	C_6H_5	77.04	154.08	231.12	308.16	385.20	462.24	539.28	616.32	693.36	770.40	1.88672
Phenylene	C_6H_4	76.03	152.06	228.10	304.13	380.16	456.19	532.22	608.26	684.29	760.32	1.88099
Sulphate	SO_4	96.06	192.12	288.18	384.24	480.30	576.36	672.42	768.48	864.54	960.60	1.98254
Sulphonic	SO_3H	81.07	162.14	243.20	324.27	405.34	486.40	567.48	648.54	729.61	810.68	1.90886
Water	H_2O	18.02	36.03	54.05	72.06	90.08	108.10	126.11	144.13	162.14	180.16	1.25565

Periodic System of Mendeleeff.

Group	O.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Volatile Hydrogen compounds					MH_4	MH_3	MH_2	MH	
Highest salt-forming oxides		M_2O	MO	M_2O_3	MO_2	M_2O_5	MO_3	M_2O_7	MO_4
Series 1		H 1·008							
,, 2	He 4·00	Li 6·94	Gl 9·1	B 10·9	C 12·005	N 14·008	O 16·00	F 19·0	
,, 3	Ne 20·2	Na 23·00	Mg 24·32	Al 27·0	Si 28·1	P 31·04	S 32·06	Cl 35·46	
,, 4	A 39·9	K 39·10	Ca 40·07	Sc 45·1	Ti 48·1	V 51·0	Cr 52·0	Mn 54·93	Fe 55·84 Co 58·97 Ni 58·68
,, 5		Cu 63·57	Zn 65·37	Ga 70·1	Ge 72·5	As 74·96	Se 79·2	Br 79·92	

	O.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Series 6	Kr 82·92	Rb 85·45	Sr 87·63	Yt 89·33	Zr 90·6	Cb 93·1	Mo 96·0	—	Ru 101·7 Rh 102·9 Pd 106·7
,, 7		Ag 107·88	Cd 112·40	In 114·8	Sn 118·7	Sb 120·2	Te 127·5	I 126·92	—
,, 8	Xe 130·2	Cs 132·81	Ba 137·37	La 139·0	Ce 140·25	—	—	—	—
,, 9	—	—	—	—	—				
,, 10	—				—	Ta 181·5	W 184·0	—	Os 190·9 Ir 193·1 Pt 195·2
,, 11		Au 197·2	Hg 200·6	Tl 204·0	Pb 207·20	Bi 209·0	—	—	—
,, 12	Nt 222·4	—	Ra 226·0	—	Th 232·15		U 238·2	—	—
Group	O.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.

PHYSICO-CHEMICAL CONSTANTS.

G. Barr, D.Sc., Verney Stott, B.A., and Edith G. Wilson, Sc.B

Thermal Constants of Elements. (After J. Mills, *Physical Chem.*, 1917).

The specific heats are the true specific heats at the temperature stated, not interval values unless an interval is given. The figures for gases are at constant volume. Specific heats and latent heats are in calories per grm. Values in italics are for modifications not mentioned by Mills; a few melting points have also been added.

Element	Specific heat at 0°C.	Specific heat solid at m.p.	Specific heat liquid at m.p.	Melting point °C.	Latent heat of fusion at m.p.	Latent heat of vaporisation at b.p.	Boiling point °C.
Aluminium	·208	·319	·308	658·	82·0	1771·	1800·
Antimony	·0486	·0608	—	630·	40·2	—	1440·
Argon	·0747 (0°–2500°C.)	—	—	−188·	—	38·8	−185·8
Arsenic, cryst.	·0794	—	—	815·	—	—	616·
amorph.	·076 (21°–65°C.)	—	—	—	—	—	—
Barium	·05 (room temp.)	—	—	850·	—	—	—
Beryllium	·376	—	—	1279·	*277·*	—	1420·
Bismuth	·0301	·0316	·0363	271·	12·39	198·9	—
Boron, cryst.	·217	—	—	2200·	—	—	—
amorph.	·307 (0°–100°C.)	—	—	—	—	—	—
Bromine	—	·106	·107	−7·4	16·18	46·0	63·1
Cadmium	·0548	·0622	—	320·9	13·7	209·7	765·9
Cæsium	·0522	·0600	·0595	28·5	3·76	—	670·
Calcium	·152	—	—	803·	—	—	—
Carbon, graphite	·156	·817	—	3600·	—	12033·	3600·
diamond	·103 (·460 at 100°C.)	—	—	—	—	—	—
charcoal	·165 (0°–24°C.) ·238 (0°–224°C.)	—	—	—	—	—	—
Cerium	·045 (0°–100°C.)	—	—	623·	—	—	—
Chlorine gas	·0806	—	·212	−103·6	22·96	69·2	−33·7
liquid	·226	·170	—	—	—	—	—
Chromium	·104	—	—	1550·	—	—	2200·
Cobalt	·099	—	—	1478·	—	—	—
Copper	·0909	·1272	—	1083·	43·3	1104·	2310·

Element.	Specific heat.			Melting point. °C.	Latent heat of fusion at m.p.	Latent heat of vaporisation at b.p.	Boiling point. °C.
	at 0°C.	at m.p. solid.	at m.p. liquid.				
Gallium	·079 (12°—23°C.)	—	·080 (13°—112°C.)	13·5	19·1	—	—
Germanium	·0737 (0°—100°C.)	—	—	900·?	—	—	—
Gold	·0302	·0349	—	1062·	16·3	395·5	2200·
Helium	·756 (−15° to 150°C.)	—	—	—	—	4·9?	−268·7
Hydrogen	2·39	—	3·4	−259·	16·0	108·6	−252·7
Indium	·057 (0°—100°C.)	—	·108	155·	—	—	—
Iodine	·0514	·0570	—	113·5	11·71	23·95	184·35
Iridium	·0312	·0485?	—	2290·	—	932·	—
Iron	·104	·167	—	1530·	69·0	—	2450·
Krypton	—	—	—	−169·	—	27·5	−151·7
Lanthanum	·045 (0°—100°C.)	—	—	810·	—	—	—
Lead	·0303	·0339	·0406	327·4	5·35	211·0	1525·
Lithium	·800	1·169	—	180·	32·81	—	>1400·
Magnesium	·238	·298	·374	650·	72·0	1933·	1120·
Manganese	·107	—	—	1260·	—	—	1900·
Mercury	·0337	·0332	·0339	−38·9	2·785	67·8	356·95
Molybdenum	·0683	—	—	2535·	—	—	—
Neon	—	—	—	—	—	—	−239·
Nickel	·103	—	—	1452·	—	—	2400·
Nitrogen	·165	—	·476	−210·5	13·7	47·75	−195·7
Osmium	·0311 (19°—98°C.)	—	—	2200·	—	—	—
Oxygen	·154	—	·347	−235·	5·7?	50·92	−182·8
Palladium	·058	·0835	—	1549·	36·3	547·	—
Phosphorus, red	·160	—	—	—	—	—	—
yellow	·175	·186	·204	44·	5·02	130·4	289·

Element.	Specific heat. at 0°C.	at m.p. solid.	at m.p. liquid.	Melting point. °C.	Latent heat of fusion at m.p.	Latent heat of vaporisation at b.p.	Boiling point. °C.
Platinum	·0310	·0418	—	1755·	27·18	650·6	—
Potassium	·1729	·1914	·1844	63·5	14·63	—	762·2
Rhodium	·0580 (10°—97°C.)	—	—	1907·	—	—	696·
Rubidium	·0802	·0919	·0911	39·0	6·15	—	696·
Ruthenium	·061 (0°—100°C.)	—	—	1900·?	—	—	688·
Selenium, cryst. ...	·079	·105	—	217·	—	—	—
amorph...	·095 (18°—38°C.)	—	—	—	—	—	—
Silicon, cryst.	·160	—	—	1414·	—	—	—
Silver, cryst.	·0556	·0730	·0748	961·	24·72	531·0	1955·
Sodium	·284	·329	·323	97·9	27·37	—	882·9
Strontium	·074 (? temp. near room)	—	—	900·	—	—	—
Sulphur, rhombic	·166	·185	·228	110·2	15·32	—	444·5
monoclinic	·174	·199	·228	114·6	11·96	339·9	—
Tantalum	·0331	—	—	2850·	—	—	—
Tellurium, cryst..	·0477	·0519	—	451·	—	—	1390·
Thallium	·0309	·0338	—	302·	7·2	—	1280·
Thorium	·028 (0°—100°C.)	—	—	1690·	—	—	—
Tin, white	·0536	·0657	·0637	231·8	14·23	597·1	2275·
Titanium	·0985	—	—	1795·	—	—	—
Tungsten	·0321	—	—	3267·	—	—	—
Uranium	·028 (0°—99°C.)	—	—	—	—	—	—
Vanadium	·124 (17°—99°C.)	—	—	1720·	—	—	—
Xenon	—	—	—	-140·	—	23·8	-109·
Zinc	·0921	·1033	·0956	419·	27·45	417·6	918·
Zirconium	·067 (0°—100°C.)	—	—	1300·?	—	—	—

Other Physical Constants of Elements and of Alloys.

Coefficient of linear expansion a in equation $l_t = l_o \ (1 + at)$. The values given are approximate (varying with previous history of the metal) and for temperatures about 20° C.

Thermal conductivities and specific electrical resistances of metals are mostly for drawn wire. The specific electric resistance is the resistance in ohms of 1 cm. length of wire 1 sq. cm. in cross-section. If the 10^6 in the heading is replaced by 10^2 the figures give the resistance per metre of wire 1 sq. mm. in section.

Element.	Coeff. of linear expansion $a \times 10^6$.	Thermal conductivity. k.	Specific electrical resistance $\times 10^6$.
Aluminium	25·5	·504	2·95
Antimony	11·5	·044	40·5
Bismuth	15.7	·019	119·
Cadmium	30·7	·222	7·5
Calcium	—	—	4·6
Carbon, gas carbon	5·4	·010	5000·
graphite	7·9	·012	3000·
diamond	1·2	—	—
Cobalt	12·4	—	9·0
Copper	16·7	·918	1·78
Gold	14·2	·700	2·42
Iridium	6·5	—	5·3
Iron, pure	11·8	·161	9·8
wrought	11·9	·144	13·9
cast	10·4	·12 – ·15	—
steel (0·1% C.)	11·	·11	20·
Lead	28·	·083	20·8
Lithium	—	—	8·9
Magnesium	26·	·376	4·3
Mercury	$\frac{1}{3} \times 18·2$	·020	94·1 (0°C.)
Molybdenum	—	—	4·1
Nickel	12·8	·142	11·8
Osmium	6·6	—	9·5
Palladium	11·7	·168	10·7
Platinum	8·9	·166	11·0
Potassium	71·	—	6·6
Rhodium	—	—	6·
Selenium	36·8	—	2×10^{22}
Silver	19·0	1·00	1·66
Sodium	61·	·36	4·8

Element or Alloy.	$a \times 10^6$.	k.	Sp. Re. $\times 10^6$.
Sulphur	66·	—	7×10^{21}
Tantalum	8·	—	14·6
Tellurium	34·	—	21·
Thallium	30·2	—	17·6
Tin	22·0	·155	11·3
Tungsten	4·4	—	5·0
Zinc	26·0	·265	6·1
Brass 66% Cu	17·8	·29	5·5
Bronze 12% Sn	23·0	—	18·
Constantan 40% Ni	14·5	·054	49·
German silver	18·	·07	30·
Invar 36% Ni	0·9	—	75·
Manganin 12% Mn, 4% Ni	—	·053	42·
Platin-iridium 10% Ir	8·7	—	24·
Solder 33% Sn	25·	—	17·

Melting Points of Alloys of Low Melting Point.

(K. Heine, 1906.)

M.P. °C.	Pb.	Sn.	Bi.	Cd.	Alloy.
60—68	26.7	13.3	50.0	10.0	Lipowitz.
65.5	25.0	12.5	50.0	12.5	Wood
67.5	25.2	14.1	51.1	9.6	,,
68.5	25.9	14.5	52.5	7.0	Newton.
75.5	25.0	14.2	50.7	10.1	Lipowitz.
80.0	21.4	21.4	57.1	—	D'Arcet.
90.0	35.0	29.9	35.1	—	Rose.
91.6	30.0	20.0	5C.0	—	Lichtenberg
91.6	32.7	12.4	54.8	—	,,
93.	25.0	25.0	50.0	—	Rose
93.7	27.9	15.9	56.2	—	,,
94.	42.1	15.8	42.1	—	,,
94.	27.5	45.0	27.5	—	Bismuth solder.
94.4	33.9	11.6	54.5	—	Newton
95.	43.3	—	50.1	6.7	Hauer.
104.0	26.3	7.5	66.2	—	Krafft.
111.0	40.0	20.0	40.0	—	Bismuth solder.
122.	29.3	21.2	39.5	—	Homberg.
155.	42.9	42.9	14.3	—	Bismuth solder.
182.	37.1	62.9	—	—	Soft solder.
	Cu.	Zn.			
870—845	50.	50.	—	—	Common brass or brazing spelter.

Melting Points of Alloys of Precious Metals.

Percentage Composition.		Temperature at which melting begins.	Temperature at which melting is complete.
Au.	Pt.		
(Doerinckel 1907)			
100	0	—	1064
90	10	1079	1174
80	20	1109	1299
70	30	1177	1437
60	40	1203	1503
50	50	1253	1544
40	60	1285	1579
[0	100 by extrapolation		1744]
Au.	Ag.		
(Raydt 1912)			
100	0	—	1064
80	20	1038	1046
60	40	1018	1028
40	60	993	1003
20	80	976	985
0	100	—	961

Specific Heat of Water.   Callendar, 1912.

15° calories.							
0°	1·0093	30	·9976	60	·9987	90	1·0036
5	1·0049	35	·9973	65	·9993	95	1·0046
10	1·0019	40	·9973	70	1·0000	100	1·0057
15	1·0000	45	·9975	75	1·0008		
20	0·9988	50	·9978	80	1·0017		
25	0·9980	55	·9982	85	1·0026		

Specific Heats and Latent Heats of Vaporisation of Common Liquids. Cals. per gm.

Latent heats of vaporisation of liquids not mentioned may be found approximately by Trouton's rule. $ML = CT$ where M is mol. wt., T is boiling point absolute and $C = 21$ for normal liquids: if liquid is associated $C > 21$, if vapour is associated $C < 21$.

	°C.	Specific heat.	B.Pt. °C.	Lt. heat of vaporisation.
Ammonia liquid	0	1·10*	(0)	(301·8)
Brine (s.g. 1·20)	0	·71	—	—
$CaCl_2$ solution (s.g. 1·20)	0	·708	—	—
Carbon dioxide liquid	0	·60*	(0)	(54·1)
disulphide	0	·235	46·2	84·9
Sulphur monochloride S_2Cl_2 ..	12—70	·220	57·	36·
Sulphur dioxide	20	·327	(0)	(91·7)
Sulphuric acid	10	·34	—	—
Sulphuryl chloride SO_2Cl_2	15—63	·233	70·	52·4
Thionyl chloride $SOCl_2$	17—60	·242	80·	54·4
Water	see table		100·	539·0†
Acetone	0	·506	56·0	124·
Amyl acetate (iso)	20	·459	139·	69·
alcohol (iso)	20	·555	130·1	116·
Aniline	15	·514	183·	104·
Benzene	0	·383	80·2	94·9
Benzyl alcohol	22—200	·540	205·3	98·5
Butyl acetate	20	·459	124·2	73·9
Carbon tetrachloride	30	·203	77·8	46·8
Chloroform	0	·232	61·	61·
Ether	0	·523	(30)	(91·3)
Ethyl acetate	20	·459	77·3	88·4
alcohol	20	·574	78·2	204.
Glycerine	20	·551	—	—
Methyl alcohol	0	·563	66·2	262·
Nitrobenzene	20	·386	210·	79·1
Pyridine	21—108	·431	114·	104·
Toluene	18	·402	110·8	87·4
Xylene m	0	·383	139·2	81·3

* At constant (saturation) pressure.
† Accurate value, 15° cals

Specific Heats and Thermal Conductivities of Misellaneous Substances.

c = specific heat cals. per gm.
k = thermal conductivity

The values are approximate and except where otherwise stated are for room temperatures.

	c.	$k \times 10^4$
Asbestos	·20	—
Cellulose 7% H_2O	·41	·4 (cotton)
Charcoal	·16	2·2
Ebonite	·40	4·2
Glass, crown	·17	25·
flint	·12	20·
Jena 16‴ & 59‴	20	15·
Ice ($-10°C.$)	·53	40·
Paraffin wax	·73	6·0
oil	·51	3·5
Porcelain ($15°-950°C.$)	·26	25·
Quartz	·18	160·
Silica (fused) 0°	·168	—
1000°	·286	—
Wood (average)	·42	5·

Latent Heats of Fusion of Compounds at Melting Point. Cals. per gm.

	°C.	Lat. heat.
Potassium nitrate	333·	25·5
Sodium nitrate	308·	45·
Sulphuric acid	10·5	26·0
Water	0·	79·6*
Acetic acid	16·54	45·8*
Benzene	5·44	30·4*
Chloral hydrate	46·	33·
Formic acid	8·	53·
Naphthalene	79·9	36·
Nitrobenzene	5·82	22·46*
Phenol	43·	24·9

*Very accurate determinations—15° calories.

Physical Properties of Gases.

c_p = specific heat at constant pressure (1 atmo.) cals. per gm.

γ = ratio of c_p to specific heat at constant volume.

η_o = viscosity at 0°C. in C.G.S. units.

C = constant in Sutherland's formla $\eta_t = \eta_o \dfrac{273 + \text{C}}{\theta + \text{C}} \cdot \left(\dfrac{\theta}{273}\right)^{3/2}$

in which θ is absolute temp.

k_o = thermal conductivity at 0° C., cals. per sq. cm. per second for temperature gradient of 1° C. per cm

β = temperature coefficient of k.

Gas.	T°	c_p	T°	γ	$\eta_o \times 10^6$	C.	$k_o \times 10^5$	$\beta \times 10^3$
Air	20°	·2408	19	1·4029	171·8	120	5·68*	3·6
	20—800	·243						
Ammonia	0	·308	—	1·336	—	—	4·58	5·5
Argon	20—90	·123	0	1·667	210	170	3·85*	3·5
Carbon monoxide	23—99	·242	0	1·401	163	102	5·0	—
dioxide ..	20	·202	25	1·300	139	240	3·53*	5·6
Chlorine	16—343	·115	16	1·329	129	—	—	—
Ethylene	25—100	·388	—	1·264	97	226	3·95	—
Helium	0—150	1·266	0	1·63	189	80	34·4*	2·8
Hydrogen	20—100	3·41	19	1·4012	84	83	41·65*	2·8
Methane	—	·59	19	1·313	104	—	7·20*	·4·8
Nitric oxide	10—180	·232	—	1·394	165	—	4·5	—
Nitrogen	0	·2350	—	1·4144	167	111	5·66*	3·4
peroxide	27—67	1·62	20	1·172	—	—	—	—
Nitrous oxide....	25—·100	·212	—	1·261	135	313	3·53*	4·4
Oxygen	20—440	·224	10	1·398	193	138	5·77*	3·6
Sulphur dioxide..	10—190	·154	25	1·26	123	—	—	—
Sulphuretted hydrogen	20—206	·245	18	1·321	115	—	.—	—
Water vapour ..	100	·435	110	1·305	88	72	3·95	—

* Signifies due to Weber, 1917.

NOTE.—In mixtures, specific heats are additive, but neither viscosity nor thermal conductivity is proportional to the concentration.

Viscosity

The C.G.S. unit of viscosity is that of a fluid in which the tangential force per sq. cm. exerted on each of two parallel planes 1 cm. apart in the fluid is one dyne when one of the planes is moving with a velocity of 1 cm. per sec. in its own plane relatively to the other.

In the capillary-tube method of determining viscosities

$$\eta = \frac{\pi p \, r^4 t}{8v(l+\lambda)} - \frac{mcv}{8\pi t(l+\lambda)}$$

where p = pressure difference between the two ends of the tube (dynes/cm.^{2}).

t = time of flow.

c = density of the fluid.

r = radius of capillary, l = length.

v = volume flowing in time t.

and m = a constant, = about 1.12.

λ = a correction for resistances outside the capillary, negligible if capillary is long compared with its radius.

From the approximate dimensions of the apparatus used find $B = \frac{mv}{8\pi l}$, then $\eta = Apt - B \dfrac{c}{t}$, and the value of A may be obtained by calibration with a substance of known viscosity, η_1 by substituting the corresponding values of p_1, t_1, and c_1, found for the standard, when $A = (\eta_1 + B \, c_1/t_1) \div p_1 t_1$

In all relative measurements of viscosity the most accurate results are obtained by using as standard substance one which has a viscosity not far removed from that being measured. In commercial viscometry, where short-tube instruments or approximate methods are likely to be used, it is best to refer the results, not in most cases to the time of flow of water, but to the viscosity or time of flow of a solution of alcohol or of cane sugar (sucrose) in water having a viscosity as near as possible to the range desired.

Bingham and Jackson (*Bull. Bureau of Standards*, 1918)

give the following values for the viscosity of standard substances in C.G.S. units.

WATER.

t°C.	$\eta \times 100.$	t°C.	$\eta \times 100.$	t°C.	$\eta \times 100.$
0	1·7921	25	0·8937	60	0·469
5	1·5188	30	0·8007	70	0·406
10	1·3077	35	0·7225	80	0·356
15	1·1404	40	0·656	90	0·316
20	1·0050	50	0·549	100	0·284

For other temperatures interpolate reciprocals of η, or, more accurately, use equation

$$1/\eta = 2 \cdot 1482 \left\{ (t - 8 \cdot 435) + \sqrt{8078 \cdot 4 + (t - 8 \cdot 435)} \right\} - 122.$$

ETHYL ALCOHOL-WATER MIXTURE containing 39% by weight of alcohol (solution of maximum viscosity).

t°C.	0	5	10	15	20	25	30	40	50
$\eta \times 100$	7·25	5·62	4·39	3·52	2·88	2·35	2·00	1·473	1·124

SUCROSE SOLUTIONS $\eta \times 100$.

t°C.	gms. sucrose in 100 gms. soln.			t°C.	gms. sucrose in 100 gms. soln.		
	20	40	60		20	40	60
0	3·804	14·77	238·	30	1·504	4·382	33·78
5	3·154	11·56	156·	35	1·331	3·762	26·52
10	2·652	9·794	109·8	40	1·193	3·249	21·28
15	2·267	7·468	74·6	50	0·970	2·497	14·01
20	1·960	6·200	56·5	60	0·808	1·982	9·83
25	1·704	5·187	43·86				

For other concentrations interpolate logs. of $\frac{1}{n} \log. \frac{\eta}{\eta_0}$ where n is normality of solution (gm. mols. sucrose per litre) and η_0 is viscosity of water at the temperature considered.

Viscosities of Various Liquids in C.G.S. units × 100
(Mostly after Thorpe and Roger).

	0°C.	20°C.	40°C.	60°C.
Acetone	—	·33	—	—
Acetic acid	—	1·22	·90	·70
Aniline	—	·44	·24	·16
Benzene	·90	·65	·49	·39
Bromine	1·26	·99	·82	—
Carbon tetrachloride	1·35	·97	·74	·58
„ disulphide.	·43	·37	·32	—
„ dioxide liq.	—	·07	—	—
Chloroform	·70	·56	·46	·39
Ether	·29	·23	—	—
Ethyl alcohol	1·77	1·19	·83	·59
Hexane (n)	·40	·32	·26	·22
Mercury	1·69	1·56	—	(100° 1·22)
Methyl alcohol	·81	·59	·45	·35
Toluene	·77	·59	·47	·38
Xylene (m)	·80	·61	·49	·40

Viscosities of Miscellaneous Substances
of High Viscosity in C.G.S. units.

Oils (Archbutt)	15°C.	100°C.
sperm	·42	·046
olive	1·01	·070
rape	1·12—1·18	·080—·085
castor	2·73 (38°C.)	·169
spindle (mineral)	·45—·73	·033—·039
machine (medium)	3·0—3·6	·08—·07
cylinder	2·0—11·0 (38°C.)	·2—·45

	η	t°C.
Glycerine (s.g. 1·262) .... ,.........	13·1 at	20
Sulphuric acid 96%...........................	0·22 at	20
Sodium nitrate, fused	0·030	305
„ „ „	0·020	355
Potassium nitrate, fused	0·021	334
„ „ „	0·017	358
Sodium chloride 20% solution in water......	0·0154	20°

Pitch (Trouton)	0°	5·1×10¹¹	15°	1·3×10¹⁰
Soda glass (Trouton)	575°	1·1×10¹³	710°	4·5×10¹⁰
Cobblers' wax (Trouton)	8°	4·7×10⁶		

Refractive Indices.

Of *Liquids* for sodium D line at 15° C. (against air).

	$n-1$.		$n-1$.
Acetic acid	·374	Ethyl alcohol	·363
anhydride	·392	ether	·355
Acetone	·361	Ethylene dibromide	·541
Amyl acetate	·406	Glycerine	·475
alcohol (*iso*)	·409	Methylene iodide	·744
Aniline	·589	Methyl alcohol	·331
Benzene	·504	Naphthalene bromide	·660
Benzyl alcohol	·541	Nitrobenzene	·554
Bromoform	·591	Phenol	·552
Canada balsam	·53	Pyridine	·509
Carbon disulphide	·631	Sulphuric acid	·420
tetrachloride	·463	Toluene	·498
Chloroform	·449	Water	·333
Ethyl acetate	·374	Xylene *m*	·499

Of *Solids* for sodium D line.

	n.	$\delta n \times 10^3$.
Diamond	2·417	24
Glass		
crown	1·50—1·52	8·5—10·0
borosilicate crown	1·48—1·52	7·6— 8·6
barium crown	1·57—1·65	10·0—13·0
flint	1·54—1·80	12·—30·
borosilicate flint	1·55—1·57	11·—12·
barium flint	1·55—1·63	10·—17·

δn is difference between refractive indices for C line and F line (Hα and Hβ).

Of *Gases* for sodium D line, reduced to N.T.P.

	$(n-1)\times10^6$.		$(n-1)\times10^6$.
Air	291·8	Hydrogen	138·4
Acetylene	565·1	Methane	443·8
Ammonia	377·	Nitrogen	298·
Argon	283·7	Nitrous oxide	515·
Carbon monoxide	334·	Nitric oxide	297·
dioxide	450·	Oxygen	272·
Chlorine	769·	Sulphur dioxide	660·
Chloroform	1456·	Sulphuretted hydrogen	619·
Ethylene	657·1	Water vapour	257·
Helium	35·0		

For n of oils see Oils, Fats and Waxes Section.

Cryoscopic Constants.

For small concentrations of dissolved substance, Raoult's law states that $\dfrac{\delta\theta}{m} = \dfrac{k_c}{M}$ where $\delta\theta$ is lowering of freezing point produced by the addition of m gms. of solute of molecular weight M to 100 gms. of solvent: k is called the cryoscopic constant of the solvent. The theoretical value of k is $\dfrac{0\cdot02\theta^2}{L}$ where θ is the absolute freezing point and L the latent heat of fusion of the solvent.

	k_c		k_c
Acetamide	36·3	Naphthalene	68·7
Acetic acid	39·0	Nitrobenze.e	69·5
Aniline	63·6	Phenol	73·
Benzene	50·	Stearic acid	43·5
Bromoform	144·	Water	18·5
Fcrmamide	38·5	Sulphuric acid	69·
Iodine	213·	Sodium sulphate $10H_2O$ ..	32·5
Methyl oxalate	52·		

Ebullioscopic Constants.

The elevation of boiling-point of a solvent by the addition to 100 gms. of it of m gms. of solvent of molecular weight M is given by the relation $\dfrac{\delta\theta}{m} = \dfrac{k_e}{M}$, provided m is small: k_e is the ebullioscopic constant. The theoretical value of k_e may be calculated from the relation $k_e = \dfrac{\cdot02\theta^2}{L}$ where θ is the absolute boiling-point at 760 mm. and L the latent heat of vaporisation at θ of the solvent. The constants given are for atmospheric pressure: Raoult gives the formula

$$k_e^1 = k_e \left\{ 1 + \cdot008(\theta^1 - \theta) \right\}$$

for the variation of the constant with pressure: k_c^1 is the

constant when the pressure change has altered the boiling point from θ to θ^1.

	k_e		k_e
Acetic acid	30·7	Ether	21·3
anhydride	35·3	Ethyl acetate	28·
Acetone	16·7	alcohol	11·9
Amyl acetate	48·3	Methyl alcohol	8·8
alcohol (*iso*)	25·7	Naphthalene	58·
Aniline	36·9	Nitrobenzene	53·
Benzene	25·6	Phenol	36·0
Carbon disulphide	23·7	Pyridine	29·
tetrachloride	48·5	Water	5·2
Chloroform	38·8		

DENSITY AND SPECIFIC GRAVITY.

The Density of a substance is defined as its mass per unit volume.

Since the volume of a given mass of any substance varies with the temperature of the substance, its density also varies with the temperature. Hence, when stating the density of a substance, it is necessary also to state the temperature to which the density refers.

Densities are usually expressed in gms. per millilitre or in gms. per cc.

From the definition of the litre * it follows that the density of water at 4°C. expressed in gms. per ml. is unity.

The Specific Gravity of a substance is the ratio of the mass of any given volume of the substance to the mass of an equal volume of water.

The temperature of the substance and also that of the water must be specified. A very commonly accepted method of expressing briefly the exact significance of the specific gravity of a substance is to use the abbreviation $\mathrm{S}\dfrac{t_s}{t_w}$

where t_s is the temperature of the substance and t_w the temperature of the water to which it is referred.

* The litre is defined as the volume occupied by 1 kilogramme of water under a pressure of 760 mm. at its temperature of maximum density (4°C). The weighing is corrected for the buoyancy of the air. According to the latest determination 1 litre=1000·027 cc. and hence the millilitre, or thousandth part of a litre, and the cubic centimetre are not identical. For many purposes the difference between the two units is negligible, amounting as it does to only 27 parts in a million, but for accurate work it must be taken into account.

Thus for example $S_{\frac{15^\circ C.}{4^\circ C.}}$ signifies that the specific gravity in question is the ratio of the mass of any given volume of the substance at 15° C. to the mass of that quantity of water which at 4° C. occupies a volume equal to that of the substance at 15° C.

The specific gravity of a substance at any temperature t_s relative to water at any temperature t_w may be converted into the density of the substance at t_s by multiplying the specific gravity $S_{\frac{t_s}{t_w}}$ by the density of water at the temperature t_w.

Since the density of water at 4°C., expressed in gms. per millilitre, is unity (see above), it follows that specific gravities expressed by $S_{\frac{t_s}{4^\circ C.}}$ are identical with densities in gms. per millilitre at the temperature t_s.

DETERMINATION OF DENSITIES AND SPECIFIC GRAVITIES.

(A) Liquids.

Since all liquids have high coefficients of cubical expansion, their densities change rapidly with change of temperature. Hence it is of fundamental importance to secure accurate temperature control in all determinations of the density, or the specific gravity, of a liquid.

(1) *By means of a hydrometer.*

When a fairly large quantity, say 500 cc., of the liquid is available, its density, or specific gravity, may be readily determined by means of a hydrometer. Results accurate to three places of decimals can be easily and rapidly obtained with a suitably scaled instrument. To obtain this precision the graduated portion of the hydrometer should be about six inches in length and cover a range of five units in the second place of decimals. For less accurate results a more closely scaled instrument may be used. The temperature of the liquid must be carefully adjusted to the standard temperature of the hydrometer, or, if readings are taken at other temperatures, suitable corrections must be applied.

Hydrometers graduated in terms of specific gravity, or density, are preferable to those graduated in arbitrary scales.

(2) *By means of a specific gravity bottle or pyknometer*

The weight of water required to fill the bottle or pyknometer must be determined, and also the weight of liquid required to fill the instrument, and from these observations the density,

or the specific gravity of the liquid may be calculated as follows :—

If W_1 = observed weight in air of water required to fill the bottle at $t°C$.

W_2 = observed weight in air of liquid required to fill the bottle at $t°C$.

D = density of liquid in gms. per ml. at $t°C$.

d = density of water in gms. per ml. at $t°C$.

S = the specific gravity of the liquid at $t°C$. relative to water at $t°C$.

$$\text{Then } D = \frac{W_2}{W} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

The approximate values given by the above formulæ may be corrected for the buoyancy effect of the air by means of the following relations :—

$$D' = D - 0.0012 (D - 1),$$
$$\text{and } S' = S - 0.0012 (S - 1),$$

where D' and S' are the corrected values.

If the weight of water W_1 is determined at t', and the weight of liquid W_2 is determined at t, then the following relations give values corrected for the temperature difference and also for the buoyancy effect of the air :—

$$D'' = D - 0.0012 (D - 1) + 0.000026 (t' - t) D,$$
$$\text{and } S'' = S - 0.0012 (S - 1) + 0.000026 (t' - t) S$$

$$\text{where } D = \frac{W_2}{W_1} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

(3) *By means of a plummet or sinker.*

The weight of the plummet in air, its weight when suspended in water, and also its weight when suspended in the liquid must be determined. Then if W_1 is the difference between the weight in air and the weight in water, and W_2 is similarly the difference between the weight in air and the weight in the liquid, the water and the liquid both being at the same temperature t, the required density or specific gravity may be determined by substituting these values in the relations given in the preceding paragraph, viz. :

$$D = \frac{W_2}{W_1} d \quad \text{and} \quad S = \frac{W_2}{W_1}$$

and to correct for the buoyancy effect of the air :

$$D' = D - 0.0012 (D-1) \text{ and } S' = S - 0.0012 (S-1)$$

Also if the temperature of the water is t' and that of the liquid t, we have as before :

$$D'' = D - 0.0012 (D - 1) + 0.000026 (t' - t) D,$$
$$\text{and } S'' = S - 0.0012 (S - 1) + 0.000026 (t' - t) S.$$

(B) SOLIDS.

(1) *By weighing in air and also in water.*

Let W_1 = weight of the solid in air.

W_2 = weight of the solid in water at temp. t.

d = density of water in gms. per ml. at t.

D = density of solid in gms. per ml. at t.

S = specific gravity of solid at t relative to water at t.

$$\text{Then } D = \frac{W_1}{W_1 - W_2} \, d, \text{ and } S = \frac{W_1}{W_1 - W_2}$$

The above approximate values may be corrected for the buoyancy effect of the air by means of the relations :

$$D' = D - 0.0012 (D - 1)$$
$$S' = S - 0.0012 (S - 1)$$

where D' and S' are the corrected values.

(2) *By means of a specific gravity bottle.*

The density, or the specific gravity, of a solid may be conveniently determined by means of a specific gravity bottle when the substance is in small fragments or in the form of a powder.

Let W_1 = weight of solid.

W_2 = weight of water at a temp. $t°C$. required to fill the bottle when it contains the weight W_1 of solid.

W_3 = weight of water at a temp. $t°C$. required to fill the bottle completely.

D = density of solid in gms. per ml. at $t°C$.

d = density of water in gms. per ml. at $t°C$.

S = specific gravity of solid at t relative to water at t.

$$\text{Then } D = \frac{W_1}{W_3 - W_2} \, d, \dots\dots\dots\dots\dots(1)$$

$$\text{and } S = \frac{W_1}{W_3 - W_2} \dots\dots\dots\dots\dots(2)$$

If W_2 is determined when the water is at a temp. $t°C$., and W_3 is determined when the water is at a temp. $t'°C$., and if d and d' are the densities of water at t and t' respectively, the quantity

$$W_3 [1 + d - d' + 0.000026 (t - t')]$$

must be used instead of W_3 in the above formulæ in order to correct for the difference in temp.

The values D and S obtained by using the relations (1) and (2) respectively (or by introducing the corrected value of W_3 in these relations) may be corrected for the buoyancy effect of the air by the usual equation :

$$D' = D - 0.0012 (D - 1)$$
$$\text{and } S' = S - 0.0012 (S - 1)$$

where D' and S' are the corrected values.

BUOYANCY CORRECTIONS FOR SPECIFIC GRAVITY DETERMINATIONS.

Sp. Gr.	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
0·6	−5	−5	−5	−4	−4	−4	−4	−4	−4	−4
0·7	−4	−3	−3	−3	−3	−3	−3	−3	−3	−3
0·8	−2	−2	−2	−2	−2	−2	−2	−2	−1	−1
0·9	−1	−1	−1	−1	−1	−1	0	0	0	0
1·0	0	0	0	0	0	+1	+1	+1	+1	+1
1·1	+1	+1	+1	+2	+2	+2	+2	+2	+2	+2
1·2	+2	+3	+3	+3	+3	+3	+3	+3	+3	+3
1·3	+4	+4	+4	+4	+4	+4	+4	+4	+5	+5
1·4	+5	+5	+5	+5	+5	+5	+6	+6	+6	+6
1·5	+6	+6	+6	+6	+6	+7	+7	+7	+7	+7
1·6	+7	+7	+7	+8	+8	+8	+8	+8	+8	+8
1·7	+8	+9	+9	+9	+9	+9	+9	+9	+9	+9
1·8	+10	+10	+10	+10	+10	+10	+10	+10	+11	+11
1·9	+11	+11	+11	+11	+11	+11	+12	+12	+12	+12
2·0	+12	+12	+12	+12	+12	+13	+13	+13	+13	+13

NOTE.

The table gives the values of $0·0012 (S − 1)$ where S is the uncorrected specific gravity, the results being expressed as units in the *fourth decimal* place. The table may also be used for correcting densities, for in this case also the correction term is $0·0012 (D − 1)$. The corrections given are to be subtracted in either case.

If the final result is required to be correct to five or more places of decimals the atmospheric conditions prevailing at the time of experiment must be noted and appropriate values for the density of the air used in calculating the buoyancy corrections (see " Density of Air half saturated with Water Vapour."). See Barr. *J.C.S.*, 1924, 1040.

Example. Suppose a specific gravity to have been calculated using a simple formula without any allowance for the buoyancy effect of the air, and found to be 0·7436. Then in the above table, under 0·74. we find the correction − 3. Hence the corrected value of the specific gravity is 0·7436 + 0·0003, *i.e.* 0·7439.

By means of this and the following table, specific gravities calculated by using one or other of the various simple formulæ* may be corrected for the buoyancy effect of the air and converted into true densities by simple addition or subtraction.

* For example $S = \dfrac{W_2}{W_1}$, where W_2 is the observed weight of a liquid required to fill a specific gravity bottle and W_1 is the observed weight of water required to fill the bottle at the same temperature.

CONVERSION OF SPECIFIC GRAVITIES TO DENSITIES.

Sp. Gr.	$S_{10°C.}^{10°C.}$	$S_{12·5°C.}^{12·5°C.}$	$S_{15°C.}^{15°C.}$	$S_{60°F.}^{60°F.}$	$S_{17°C.}^{17°C.}$	$S_{17·5°C.}^{17·5°C.}$	$S_{20°C.}^{20°C.}$
0·60	16	32	52	58	72	77	106
0·65	18	35	57	62	78	83	115
0·70	19	37	61	67	84	90	124
0·75	20	40	66	72	90	96	132
0·80	22	43	70	77	96	103	141
0·85	23	45	74	81	102	109	150
0·90	24	48	79	86	108	116	159
0·95	26	51	83	91	114	122	168
1·00	27	53	87	96	120	129	177
1·05	29	56	92	100	126	135	185
1·10	30	59	96	106	131	141	194
1·15	31	61	100	110	137	148	203
1·20	33	64	105	115	143	154	212
1·25	34	67	109	120	149	161	221
1·30	35	69	114	125	155	167	230
1·35	37	72	118	130	161	173	238
1·40	38	75	122	134	167	180	247
1·45	39	77	127	139	173	186	256
1·50	41	80	131	144	179	193	265
1·55	42	83	135	149	185	199	274
1·60	43	85	140	154	191	206	282
1·65	45	88	144	158	197	212	291
1·70	46	91	148	163	203	218	300
1·75	48	93	153	168	209	225	309
1·80	49	96	157	173	215	231	318
1·85	50	99	162	177	221	238	326
1·90	52	101	166	182	227	244	335
1·95	53	104	170	187	233	250	344
2·00	54	107	175	192	239	257	353

NOTE.

The values given in the table are expressed as units in the fifth decimal place.

To convert the specific gravity of a substance to the density at the same temperature the amount given in the table opposite to the specific gravity in question must be *subtracted* from the specific gravity.

Example. The specific gravity of a liquid at 60°F. relative to water at 60°F. as unity is 1·32672.

In the table under $S_{60°F.}^{60°F.}$ and opposite to 1·30 we find 125, and opposite to 1·35 we find 130; hence by inspection the correction for 1·32672 is 128.

The density of the liquid in gms. per millilitre at 60°F. is hence 1·32672 − 0·00128, *i.e.* 1·32544 gms./ml.

DENSITY OF WATER IN GRAMMES PER MILLILITRE *
From 0°C. to 41°C.

°C.	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	0·9998681	8747	8812	8875	8936	8996	9053	9109	9163	9216
1	9267	9315	9363	9408	9452	9494	9534	9573	9610	9645
2	9679	9711	9741	9769	9796	9821	9844	9866	9887	9905
3	9922	9937	9951	9962	9973	9981	9988	9994	9998	0000
4	1·0000000	9999	9996	9992	9986	9979	9970	9960	9947	9934
5	0·9999919	9902	9884	9864	9842	9819	9795	9769	9742	9713
6	9682	9650	9617	9582	9545	9507	9468	9427	9385	9341
7	9296	9249	9201	9151	9100	9048	8994	8938	8881	8823
8	8764	8703	8641	8577	8512	8445	8377	8308	8237	8165
9	8091	8017	7940	7863	7784	7704	7622	7539	7455	7369
10	7282	7194	7105	7014	6921	6826	6729	6632	6533	6432
11	6331	6228	6124	6020	5913	5805	5696	5586	5474	5362
12	5248	5132	5016	4898	4780	4660	4538	4415	4291	4166
13	4040	3912	3784	3654	3523	3391	3257	3122	2986	2850
14	2712	2572	2431	2289	2147	2003	1858	1711	1564	1416
15	1266	1114	0962	0809	0655	0499	0343	0185	0026	9865
16	0·9989705	9542	9378	9214	9048	8881	8713	8544	8373	8202
17	8029	7856	7681	7505	7328	7150	6971	6791	6610	6427
18	6244	6058	5873	5686	5498	5309	5119	4927	4735	4541
19	4347	4152	3955	3757	3558	3358	3158	2955	2752	2549
20	2343	2137	1930	1722	1511	1301	1090	0878	0663	0449
21	0233	0016	9799	9580	9359	9139	8917	8694	8470	8245
22	0·9978019	7792	7564	7335	7104	6873	6641	6408	6173	5938
23	5702	5466	5227	4988	4747	4506	4264	4021	3777	3531
24	3286	3039	2790	2541	2291	2040	1788	1535	1280	1026
25	0770	0513	0255	9997	9736	9476	9214	8951	8688	8423
26	0·9968158	7892	7624	7356	7087	6817	6545	6273	6000	5726
27	5451	5176	4898	4620	4342	4062	3782	3500	3218	2935
28	2652	2366	2080	1793	1505	1217	0928	0637	0346	0053
29	0·9959761	9466	9171	8876	8579	8282	7983	7684	7383	7083
30	6780	6478	6174	5869	5564	5258	4950	4642	4334	4024
31	3714	3401	3089	2776	2462	2147	1832	1515	1198	0880
32	0561	0241	9920	9599	9276	8954	8630	8304	7979	7653
33	0·9947325	6997	6668	6338	6007	5676	5345	5011	4678	4343
34	4007	3671	3335	2997	2659	2318	1978	1638	1296	0953
35	0610	0267	9922	9576	9230	8883	8534	8186	7837	7486
36	0·9937136	6784	6432	6078	5725	5369	5014	4658	4301	3943
37	3585	3226	2866	2505	2144	1782	1419	1055	0691	0326
38	0·9929960	9593	9227	8859	8490	8120	7751	7380	7008	6636
39	6263	5890	5516	5140	4765	4389	4011	3634	3255	2876
40	2497	2116	1734	1352	0971	0587	0203	9818	9433	9047
41	0·9918661									

DENSITY OF WATER IN GRAMMES PER MILLILITRE FROM 40°C. TO 100°C.*

°C.	0	1	2	3	4	5	6	7	8	9
40	0·99224	186	147	107	066	024	982	940	896	852
50	0·98807	762	715	669	621	573	525	475	425	375
60	324	272	220	167	113	059	005	950	894	838
70	0·97781	723	665	607	548	489	429	368	307	245
80	183	120	057	994	930	865	800	734	668	601
90	0·96534	467	399	330	261	192	122	051	981	909
100	0·95838									

* M. Thiesen. *Wiss. Abhand. Phys.-Tech. Reich.* Vol. iv, Part 1, p. 32, 1904.

Density of Mercury in gms. per c.c. from —20°C. to 360°C.

°C.	D.	°C.	D.	°C.	D.
−20	13.6199	110	13.3274	240	13.0173
−10	13.6446	120	13.3034	250	12.9935
0	13.5952	130	13.2794	260	12.9697
10	13.5705	140	13.2554	270	12.9459
20	13.5459	150	13.2315	280	12.9221
30	13.5214	160	13.2076	290	12.8982
40	13.4970	170	13.1838	300	12.8743
50	13.4726	180	13.1600	310	12.8504
60	13.4483	190	13.1362	320	12.8265
70	13.4240	200	13.1124	330	12.8024
80	13.3998	210	13.0886	340	12.7784
90	13.3756	220	13.0648	350	12.7543
100	13.3515	230	13.0410	360	12.7301

This and the following tables are based on determinations of the density of mercury at 0°C. by Marek, 1883, and by Thiesen and Scheele, 1897, and the expansion formula given by Donaldson, 1913.

Density of Mercury in gms. per c.c. from 0°C. to 40°C.

°C.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	13.5952	49	47	44	42	39	37	34	32	29
1	13.5927	24	22	19	17	15	12	10	07	05
2	13.5902	00	97*	95*	92*	90*	87*	85*	82*	80*
3	13.5878	75	73	70	68	65	63	60	58	55
4	13.5853	50	48	46	43	41	38	36	33	31
5	13.5828	26	23	21	18	16	13	11	09	06
6	13.5804	01	99*	96*	94*	91*	89*	86*	84*	82*
7	13.5779	77	74	72	69	67	64	62	59	57
8	13.5754	52	50	47	45	42	40	37	35	32
9	13.5730	27	25	22	20	17	15	13	10	08
10	13.5705	03	00	98*	95*	93*	90*	88*	85*	83*
11	13.5681	78	76	73	71	68	66	63	61	58
12	13.5656	53	51	49	46	44	41	39	36	34
13	13.5631	29	26	24	22	19	17	14	12	09
14	13.5607	04	02	99*	97*	95*	92*	90*	87*	85*
15	13.5582	80	77	75	72	70	67	65	63	60
16	13.5558	55	53	50	48	45	43	41	38	36
17	13.5533	31	28	26	23	21	18	16	13	11
18	31.5509	06	04	01	99*	96*	94*	91*	89*	86*
19	13.5484	82	79	77	74	72	69	67	64	62
20	13.5459	57	55	52	50	47	45	42	40	37
21	13.5435	32	30	28	25	23	20	18	15	13
22	13.5410	08	05	03	01	98*	96*	93*	91*	88*
23	13.5386	83	81	79	76	74	71	69	66	64
24	13.5361	59	56	54	52	49	47	44	42	39
25	13.5337	34	32	30	27	25	22	20	17	15
26	13.5312	10	07	05	03	00	98*	95*	93*	90*
27	13.5288	85	83	81	78	76	73	71	68	66
28	13.5263	61	58	56	54	51	49	46	44	41
29	13.5239	36	34	32	29	27	24	22	19	17
30	13.5214	12	09	07	05	02	00	97*	95*	92*
31	13.5190	87	85	83	80	78	75	73	70	68
32	13.5165	63	60	58	56	53	51	48	46	43
33	13.5141	39	36	34	31	29	26	24	21	19
34	13.5116	14	12	09	07	04	02	99*	97*	94*
35	13.5092	90	87	85	82	80	77	75	72	70
36	13.5068	65	63	60	58	55	53	50	48	46
37	13.5043	41	38	36	33	31	28	26	24	21
38	13.5019	16	14	11	09	06	04	02	99*	97*
39	13.4994	91	89	87	84	82	80	77	75	72
40	13.4970	67	65	63	60	58	55	53	50	48

DENSITIES OF METALS.

The values given are in gms. per cc. at the ordinary room temperature unless otherwise stated.

Density × 62·335 = lbs. per c. ft.

Aluminium - - - - - - -	2·70
Commercial wrought, 2·67; cast, - - -	2·56
Wire (free from SiO_2) - - - -	2·70
Pure - - - - - - -	2·58
Liquid at M.P. (720°C.) - - -	2·43
Antimony - - - - - -	6·62
Distilled in vacuo - - - - -	6·62
,, ,, and compressed - -	6·69
Amorphous - - - - - -	6·22
Liquid at M.P. (620°C.) - - -	6·41
Arsenic - - - - - -	5·72
Crystalline, grey, 5·72; black, - -	4·64
Amorphous, brown - - - -	3·70
Bismuth - - - - - -	9·80
Distilled in vacuo - - - -	9·78
Electrolytic - - - - -	9·75
Wire - - - - - -	9·85
Solid at M.P. (271°C.) - - -	9·67
Liquid ,, ,, - - -	10·00
Cadmium - - - - - -	8·64
Rolled - - - - - -	8·66
Distilled in vacuo - - - -	8·65
Wire, cold drawn - - - -	8·64
Solid at M.P. (318°C.) - - -	8·37
Liquid ,, ,, - - -	7·99
Copper - - - - - -	8·93
Cast - - - - - -	8·30—8·92
Wire - - - - - -	8·93—8·95
Beaten - - - - - -	8·92—8·96
Electrolytic - - - - -	8·88—8·95
Distilled in vacuo - - - -	8·93
Gold - - - - - -	19·3
Cast - - - - - -	19·29
Rolled - - - - - -	19·31
Wire : soft drawn, 19·26; hard drawn, -	19·25
Crystalline from solution - - -	19·43
Iron - - - - - -	7·86
Pure - - - - - -	7·85—7·88
Wrought - - - - -	7·79—7·85
Cast : grey, 7·03—7·13; white, -	7·58—7·73
Piano wire, 7·78; annealed, - -	7·80

B

DENSITIES OF METALS (*contd.*).

Lead
Lead - - - - - - - -	11·34
Cast - - - - - - - -	11·34
Rolled - - - - - - -	11·35
Wire - - - - - - -	11·34
Distilled in vacuo - - - - - -	11·34
Solid at M.P. (325°C.) - - - -	11·01
Liquid ,, ,, - - - -	10·65
Nickel - - - - - - -	8·8
Cast - - - - - - -	8·90
Malleable, sheets, etc. - - - -	8·84
Wire, cold drawn - - - - -	8·76
,, ,, ,, annealed - - -	8·84
Platinum - - - - - - -	21·4
Pure, cast and beaten - - - -	21·4
Wire, cold drawn - - - - -	21·4
Platinum sponge - - - - -	21·2
Silver - - - - - - -	10·50
Cast - - - - - - -	10·42—10·51
Commercial, pure - - - - -	10·36
Electrolytic - - - - - -	10·53
Tin - - - - - - - -	7·28
Commercial Tin (white Tetragonal).	
Cast - - - - - - -	7·28—7·30
Solid at M.P. (226°C.) - - -	7·18
Liquid ,, ,, - - -	6·99
Rhombic modification - - - -	6·56
Grey modification - - - -	5·75—5·85
Zinc - - - - - - -	7·1
Cast, cooled slowly - - - -	7·10—7·16
,, cooled quickly - - - -	7·04—7·14
Rolled - - - - - - -	7·19
Distilled in vacuo - - - - -	6·92
,, ,, and compressed - -	7·13

DENSITIES OF ALLOYS.

The values given below are in gms. per cc. at ordinary temperatures. Compositions are percentage by weight.

Brass, Yellow, 70 Cu + 30 Zn, cast - - - -	8·44
,, ,, ,, ,, rolled - - - -	8·56
,, ,, ,, ,, drawn - - - -	8·70
,, Red, 90 Cu + 10 Zn - - - - -	8·60
,, White, 50 Cu + 50 Zn - - - - -	8·20
Bronze, 90 Cu + 10 Sn - - - - -	8·78
,, 85 Cu + 15 Sn - - - - -	8·89
,, 80 Cu + 20 Sn - - - - -	8·74
,, 75 Cu + 25 Sn - - - - -	8·83

DENSITIES OF ALLOYS (contd.).

German Silver, 26·3 Cu + 36·6 Zn + 36·8 Ni	- -	8·30
,, ,, 52 Cu + 26 Zn + 22 Ni	- -	8·45
,, ,, 59 Cu + 30 Zn + 11 Ni	- -	8·34
,, ,, 63 Cu + 30 Zn + 6 Ni	- -	8·30
Monel Metal	- -	8.80
Copper and Aluminium, 97 Cu + 3 Al	- -	8·69
,, ,, 95 Cu + 5 Al	- -	8·37
,, ,, 90 Cu + 10 Al	- -	7·69
Aluminium and Zinc, 91 Al + 9 Zn	- -	2·80
Wood's Metal, 50 Bi + 25 Pb + 12·5 Cd + 12·5 Sn	-	9.70
Bismuth, Lead and Tin, 53 Bi + 40 Pb + 7 Sn	-	10·56
Antimony and Bismuth, 54 Sb + 46 Bi	- -	7·86
Antimony and Tin, 51·4 Sb + 48·6 Sn	- -	11·46
,, ,, 9·5 Sb + 90·5 Sn	- -	9·36
Iron and Silicon (Durion), 84·5 Fe + 14 Si + 1·5 other		
Elements	- -	7·00
Iron and Antimony, 55 Fe + 45 Sb	- -	8·16
Tin and Cadmium, 68 Sn + 32 Cd	- -	7·70
Lead and Tin, 87·5 Pb + 12·5 Sn	- -	10·60
,, ,, 84 Pb + 16 Sn	- -	10·33
,, ,, 77·8 Pb + 22·2 Sn	- -	10·05
,, ,, 63·7 Pb + 36·3 Sn	- -	9·43
,, ,, 46·7 Pb + 53·3 Sn	- -	8·73
,, ,, 30·5 Pb + 69·5 Sn	- -	8·24
Lead and Mercury, 51 Pb + 49 Hg	- -	12.48
Mercury and Tin, 77·5 Hg + 22·5 Sn	- -	11·46
,, ,, 46·3 Hg + 53·7 Sn	- -	9·36
Silver and Lead, 51 Ag + 49 Pb	- -	10·92
,, ,, 2 Ag + 98 Pb	- -	11·33
Silver and Copper, 94·4 Ag + 5·6 Cu	- -	10·36
,, ,, 89·3 Ag + 10·7 Cu	- -	10·30
,, ,, 66·3 Ag + 33·7 Cu	- -	10·00
,, ,, 49·65 Ag + 50·35 Cu	- -	9·65
,, ,, 29·5 Ag + 70·5 Cu	- -	9·32
Gold and Silver, 78·5 Au + 21·5 Ag	- -	16·35
,, ,, 64·6 Au + 35·4 Ag	- -	14·87
,, ,, 47·7 Au + 52·3 Ag	- -	13·43
,, ,, 23·5 Au + 76·5 Ag	- -	11·76
Gold and Copper, 98 Au + 2 Cu	- -	18·84
,, ,, 96 Au + 4 Cu	- -	18·36
,, ,, 94 Au + 6 Cu	- -	17·95
,, ,, 92 Au + 8 Cu	- -	17·52
Gold and Lead, 8·7 Au + 91·3 Pb	- -	11·84
Platinum and Iridium, 90 Pt + 10 Ir	- -	21·62
,, ,, 85 Pt + 15 Ir	- -	21·62
,, ,, 66·7 Pt + 33·3 Ir	- -	21·87
,, ,, 5 Pt + 95 Ir	- -	22·38

DENSITIES OF VARIOUS SUBSTANCES.

The values given below are approximate densities in gms. per cc. at ordinary room temperature.

$$\text{Density} \times 62{\cdot}335 = \text{lbs. per c. ft.}$$

Asbestos ....2·1—2·8	Leather ....0·9—1·0
„ board ....1·2	Loam ....1·5—2·3
Basalt ....2·7—3·2	Marble ....2·5—2·8
Bone ....1·7—2·0	Marl ....2·3—2·5
Brickwork ....1·5—1·7	Masonry ....2·4
Celluloid ....1·4	Methylated Spirit ....0·8
Cement (wood) ......2·7—3·0	Milk ....1·03
Charcoal (wood) .....0·3—0·6	Mortar (lime) apparent ...1·8
Coke (absolute density) .....1·4	Paper ....0·7—1·1
„ (apparent) „ ....0·5	Paraffin Wax ....0·8—0·9
Cork ....0·2	Pitch ....1·1
Cotton (air dried) ....1·5	Porcelain ....2·2—2·5
Ebonite ....1·2	Pumice, natural ....0·4—0·9
Fire Brick ....1·8—2·2	Resin (pine) ....1·1
Flax (air dried) ....1·5	Sand-dry absolute ....1·5
Gas Carbon ....1·8—2·0	„ apparent ....2·6
Gelatine ....1·3	Sandstone ....2·2—2·5
Glass, Bottle ....2·6—2·7	„ artificial ....2·0
Crown ordinary ......2·4	Sea-water ....1·03
Crystal „ ......3·3	Silica fused transparent .....2·2
Flint ....2·9—3·4	„ „ translucent .....2·1
Plate ....2·5	Silk, natural ....1·6
Window ....2·5	Slag ....2·5—3·0
Glue ....1·3	Slaked lime, apparent ..1·3—1·4
Granite ....2·5—3·0	Slate ....2·6—2·7
Gum arabic ....1·3—1·4	Steel ....7·8—7·9
Gutta Percha ....1·0	Tile ....1·8
India Rubber, raw .....0·9—1·0	Turpentine ....0·9
„ „ vulcanised 1·2—1·7	Vinegar ....1·1
Ivory ....1·8—1·9	Wool (air dried) ....1·3

Seasoned woods:

Alder ....0·5	Lignum-vitæ ....1·2—1·4
Ash ....0 7—0·8	Mahogany ....0·6—0·8
Bamboo ....0·4	Maple ....0·7
Beech ....0·7	Oak ....0·7—1·0
Birch ....0·7	Pine (white) ....0·5—0·6
Cedar ....0·5—0·7	Pine (yellow) ....0·5—0·8
Cypress ....0·5	Poplar ....0·4—0·5
Ebony ....1·2	Teak ....0·8—0·9
Elm ....0·6—0·7	Walnut ....0·7
Larch ....0·5	Willow ....0·5—0·6

SPECIFIC GRAVITIES AND DENSITIES OF SOLUTIONS.

Density of Aqueous Solutions of Acetic Acid.

(Oudemans, *Zs. f. Chemie*, 1866.)

$g\%$ = gms. of acid in 100 grms. of solution

$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$
1	1.0007	26	1.0363	51	1.0623	76	1.0747
2	022	27	375	52	631	77	748
3	037	28	388	53	638	78	748
4	052	29	400	54	646	79	748
5	067	30	412	55	653	80	748
6	083	31	424	56	660	81	747
7	098	32	436	57	666	82	746
8	113	33	447	58	673	83	744
9	127	34	459	59	679	84	742
10	142	35	470	60	685	85	739
11	157	36	481	61	691	86	736
12	171	37	492	62	697	87	731
13	185	38	502	63	702	88	726
14	200	39	513	64	707	89	720
15	214	40	523	65	712	90	713
16	228	41	533	66	717	91	705
17	242	42	543	67	721	92	696
18	256	43	552	68	725	93	686
19	270	44	562	69	729	94	674
20	284	45	571	70	733	95	660
21	298	46	580	71	737	96	644
22	311	47	589	72	740	97	625
23	324	48	598	73	742	98	604
24	337	49	607	74	744	99	580
25	350	50	615	75	746	100	553

Note that the specific gravity attains a maximum in the neighbourhood of 80% of acid.

Density of Mixtures of Ethyl Alcohol and Water at Various Temperatures.

The whole of the following tables relating to mixtures of ethyl alcohol and water are based on the results obtained at the Bureau of Standards, Washington. See *Bulletin of the Bureau of Standards*, Vol. 9, No. 3; and *Circular of the Bureau of Standards*, No. 19, 1916. For excise purposes in England, the table in the " Spirits " section is used.

$g\%$ = weight of alcohol in 100 gms. of mixture.

$g\%$	$S_{10°C.}/4°C.$	$S_{15°C.}/4°C.$	$S_{20°C.}/4°C.$	$S_{25°C.}/4°C.$	$S_{30°C.}/4°C.$	$S_{35°C.}/4°C.$	$S_{40°C.}/4°C.$
0	0.99973	0.99913	0.99823	0.99708	0.99568	0.99406	0.99225
1	785	725	636	520	379	217	034
2	602	542	453	336	194	031	.98846
3	426	365	275	157	014	.98849	663
4	258	195	103	.98984	.98839	672	485
5	098	032	.98938	817	670	501	311
6	.98946	.98877	780	656	507	335	142
7	801	729	627	500	347	172	.97975
8	660	584	478	346	189	009	808
9	524	442	331	193	031	.97846	641
10	393	304	187	043	.97875	685	475
11	267	171	047	.97897	723	527	312
12	145	041	.97910	753	573	371	150
13	026	.97914	775	611	424	216	.96989
14	.97911	790	643	472	278	063	829
15	800	669	514	334	133	.96911	670
16	692	552	387	199	.96990	760	512
17	583	433	259	062	844	607	352
18	473	313	129	.96923	697	452	189
19	363	191	.96997	782	547	294	023
20	252	068	864	639	395	134	.95856
21	139	.96944	729	495	242	.95973	687
22	024	818	592	348	087	809	516
23	.96907	689	453	199	.95929	643	343
24	787	558	312	048	769	476	168
25	665	424	168	.95895	607	306	.94991
26	539	287	020	738	442	133	810
27	406	144	.95867	576	272	.94955	625
28	268	.95996	710	410	098	774	438

$g\%$ = weight of alcohol in 100 gms. of mixture.

$g\%$	$\dfrac{S_{10°C.}}{4°C.}$	$\dfrac{S_{15°C.}}{4°C.}$	$\dfrac{S_{20°C.}}{4°C.}$	$\dfrac{S_{25°C.}}{4°C.}$	$\dfrac{S_{30°C.}}{4°C.}$	$\dfrac{S_{35°C.}}{4°C.}$	$\dfrac{S_{40°C.}}{4°C.}$
29	.96125	.95844	.95548	.95241	.94922	.94590	.94248
30	.95977	686	382	067	741	403	055
31	823	526	212	.94890	557	214	.93860
32	665	357	038	709	370	021	662
33	502	186	.94860	525	180	.93825	461
34	334	011	679	337	.93986	626	257
35	162	.94832	494	146	790	425	051
36	.94986	650	306	.93952	591	221	.92843
37	805	464	114	756	390	016	634
38	620	273	.93919	556	186	.92808	422
39	431	079	720	353	.92979	597	208
40	238	.93882	518	148	770	385	.91992
41	042	682	314	.92940	558	170	774
42	.93842	478	107	729	344	.91952	554
43	639	271	.92897	516	128	733	332
44	433	062	685	301	.91910	513	108
45	226	.92852	472	085	692	291	.90884
46	017	640	257	.91868	472	069	660
47	.92806	426	041	649	250	.90845	434
48	593	211	.91823	429	028	621	207
49	379	.91995	604	208	.90805	396	.89979
50	162	776	384	.90985	580	168	750
51	.91943	555	160	760	353	.89940	519
52	723	333	.90936	534	125	710	288
53	602	110	711	307	.89896	479	056
54	279	.90885	485	079	667	248	.88823
55	055	659	258	.89850	437	016	589
56	.90831	433	031	621	206	.88784	356
57	607	207	.89803	392	.88975	552	122
58	381	.89980	574	162	744	319	.87888
59	154	752	344	.88931	512	085	653
60	.89927	523	113	699	278	.87851	417
61	698	293	.88882	466	044	615	180
62	468	062	650	233	.87809	379	.86943
63	237	.88830	417	.87998	574	142	705
64	006	597	183	763	337	86905	466

$g\%$ = weight of alcohol in 100 gms. of mixture.

$g\%$	$\dfrac{S_{10°C.}}{4°C.}$	$\dfrac{S_{15°C.}}{4°C.}$	$\dfrac{S_{20°C.}}{4°C.}$	$\dfrac{S_{25°C.}}{4°C.}$	$\dfrac{S_{30°C.}}{4°C.}$	$\dfrac{S_{35°C.}}{4°C.}$	$\dfrac{S_{40°C.}}{4°C.}$
65	.88774	.88364	.87948	.87527	.87100	.86667	.86227
66	541	130	713	291	.86863	429	.85987
67	308	.87895	477	054	625	190	747
68	074	660	241	.86817	387	.85950	507
69	.87839	424	004	579	148	710	266
70	602	187	.86766	340	.85908	470	025
71	365	.86949	527	100	667	228	.84783
72	127	710	287	.85859	426	.84986	540
73	.86888	470	047	618	184	743	297
74	648	229	.85806	376	.84941	500	053
75	408	.85988	564	134	698	257	.83809
76	168	747	322	.84891	455	013	564
77	.85927	505	079	647	211	.83768	319
78	685	262	.84835	403	.83966	523	074
79	442	018	590	158	720	277	.82827
80	197	.84772	344	.83911	473	029	578
81	.84950	525	096	664	224	.82780	329
82	702	277	.83848	415	.82974	530	079
83	453	028	599	164	724	279	.81828
84	203	.83777	348	.82913	473	027	576
85	.83951	535	095	660	220	.81774	322
86	697	271	.82840	405	.81965	519	067
87	441	014	583	148	708	262	.80811
88	181	.82754	323	.81888	448	003	552
89	.82919	492	062	626	186	.80742	291
90	654	227	.81797	362	.80922	478	028
91	386	.81959	529	094	655	211	.79761
92	114	688	257	80823	384	.79941	491
93	.81839	413	.80983	549	111	659	220
94	561	134	705	272	.79835	393	.78947
95	278	.80852	424	.79991	555	114	670
96	.80991	566	138	706	271	.78831	388
97	698	274	.79846	415	.78981	542	100
98	399	.79975	547	117	684	247	.77806
99	094	670	243	.78814	382	.77946	507
100	.79784	360	.78934	505	075	641	203

SPECIFIC GRAVITY AND COMPOSITION OF MIXTURES OF ETHYL ALCOHOL AND WATER AT 60°F.

$V\%$ = volume of alcohol in 100 cc. of mixture at 60° F.
$g\%$ = weight of alcohol in 100 gms. of mixture.

V%	g%	$S\frac{60°F}{60°F}$	V%	g%	$S\frac{60°F.}{60°F.}$	V%	g%	$S\frac{60°F.}{60°F.}$	V%	g%	$S\frac{60°F.}{60°F.}$
0	0.000	1.00000	25	20.443	.97084	50	42.487	.93426	75	67.870	.87728
1	0.795	.99850	26	21.285	.96978	51	43.428	230	76	68.982	465
2	1.593	703	27	22.127	870	52	44.374	031	77	70.102	199
3	2.392	559	28	22.973	760	53	45.326	.92830	78	71.234	.86929
4	3.194	419	29	23.820	648	54	46.283	626	79	72.375	656
5	3.998	282	30	24.670	534	55	47.245	419	80	73.526	380
6	4.804	150	31	25.524	418	56	48.214	210	81	74.686	100
7	5.612	022	32	26.382	296	57	49.187	.91999	82	75.858	.85817
8	6.422	.98899	33	27.242	170	58	50.167	784	83	77.039	531
9	7.234	779	34	28.104	041	59	51.154	565	84	78.233	240
10	8.047	661	35	28.971	.95908	60	52.147	344	85	79.441	.84944
11	8.862	544	36	29.842	770	61	53.146	120	86	80.662	642
12	9.679	430	37	30.717	628	62	54.152	.90893	87	81.897	336
13	10.497	319	38	31.596	482	63	55.165	664	88	83.144	025
14	11.317	210	39	32.478	332	64	56.184	434	89	84.408	.83707
15	12.138	104	40	33.364	178	65	57.208	202	90	85.689	382
16	12.961	.97998	41	34.254	020	66	58.241	.89967	91	86.989	049
17	13.786	895	42	35.150	.94858	67	59.279	729	92	88.310	.82705
18	14.612	794	43	36.050	693	68	60.325	489	93	89.652	351
19	15.440	694	44	36.955	524	69	61.379	245	94	91.025	.81984
20	16.269	596	45	37.865	351	70	62.441	.88999	95	92.423	603
21	17.100	496	46	38.778	174	71	63.511	751	96	93.851	206
22	17.933	395	47	39.697	.93993	72	64.588	499	97	95.315	.80792
23	18.768	293	48	40.622	808	73	65.674	244	98	96.820	356
24	19.604	189	49	41.551	619	74	66.768	.87987	99	98.381	.79889
25	20.443	084	50	42.487	426	75	67.870	728	100	100.000	389

SPECIFIC GRAVITY AND COMPOSITION OF MIXTURES OF ETHYL ALCOHOL AND WATER AT 60° F.

$V\%$ = volume of alcohol in 100 cc. of mixture at 60° F.

$g\%$ = weight of alcohol in 100 gms. of mixture.

$g\%$	V%	$S\frac{60°F.}{60°F.}$	$g\%$	V%	$S\frac{60°F.}{60°F.}$	$g\%$	V%	$S\frac{60°F.}{60°F.}$	$g\%$	V%	$S\frac{60°F.}{60°F.}$
0	0.000	1.00000	25	30.388	.96489	50	57.830	.91821	75	81.269	.86024
1	1.257	.99812	26	31.555	351	51	58.844	600	76	82.121	.85783
2	2.510	629	27	32.719	207	52	59.852	377	77	82.967	541
3	3.758	452	28	33.879	057	53	60.854	153	78	83.805	298
4	5.002	282	29	35.033	.95903	54	61.850	.90927	79	84.636	052
5	6.243	118	30	36.181	745	55	62.837	701	80	85.459	.84806
6	7.479	.98963	31	37.323	582	56	63.820	475	81	86.275	558
7	8.712	813	32	38.459	414	57	64.798	249	82	87.083	310
8	9.943	667	33	39.590	242	58	65.768	022	83	87.885	061
9	11.169	524	34	40.716	065	59	66.732	.89793	84	88.678	.83810
10	12.393	386	35	41.832	.94886	60	67.690	563	85	89.464	557
11	13.613	253	36	42.944	703	61	68.641	333	86	90.240	302
12	14.832	122	37	44.050	516	62	69.586	101	87	91.008	046
13	16.047	.97993	38	45.149	325	63	70.523	.88869	88	91.766	.82788
14	17.259	869	39	46.242	130	64	71.455	636	89	92.517	523
15	18.469	747	40	47.328	.93933	65	72.380	402	90	93.254	260
16	19.676	627	41	48.407	732	66	73.299	167	91	93.982	.81991
17	20.880	508	42	49.480	527	67	74.211	.87932	92	94.700	719
18	22.081	388	43	50.545	319	68	75.117	698	93	95.407	443
19	23.278	264	44	51.605	110	69	76.016	461	94	96.103	164
20	24.472	140	45	52.658	.92899	70	76.909	224	95	96.787	.80881
21	25.662	014	46	53.705	687	71	77.794	.86986	96	97.459	595
22	26.849	.96887	47	54.746	472	72	78.672	746	97	98.117	303
23	28.032	756	48	55.780	256	73	79.544	506	98	98.759	005
24	29.210	624	49	56.808	039	74	80.410	266	99	99.386	.79700
25	30.388	489	50	57.830	.91821	75	81.269	024	100	100.000	389

COMPOSITION OF ETHYL ALCOHOL AND WATER MIXTURES AT 60°F.

$V\%$ = percentage of alcohol by volume.
G_M = mass in gms. of 1 litre of mixture.
G_A = mass in gms. of alcohol contained in 1 litre of mixture.
V_A = volume in millilitres of alcohol required to make 1 litre of mixture.
V_W = volume in millilitres of water required to make 1 litre of mixture.
v = contraction in millilitres due to admixture.

$V\%$	G_M	G_A	V_A	V_W	v
0	999.04	0.00	0	1000.00	0.00
1	997.54	7.93	10	990.56	0.56
2	996.07	15.86	20	981.15	1.15
3	994.64	23.79	30	971.78	1.78
4	993.24	31.73	40	962.43	2.43
5	991.87	39.66	50	953.12	3.12
6	990.85	47.59	60	943.87	3.87
7	989.27	55.52	70	934.65	4.65
8	988.01	63.45	80	925.48	5.48
9	986.84	71.38	90	916.34	6.34
10	985.66	79.31	100	907.22	7.22
11	984.49	87.24	110	898.11	8.11
12	983.36	95.18	120	889.03	9.03
13	982.25	103.11	130	879.98	9.98
14	981.16	111.04	140	870.96	10.96
15	980.10	118.97	150	861.96	11.96
16	979.04	126.90	160	852.96	12.96
17	978.01	134.83	170	843.99	13.99
18	977.00	142.76	180	835.04	15.04
19	976.00	150.69	190	826.01	16.01
20	975.02	158.63	200	817.17	17.17
21	974.03	166.56	210	808.25	18.25
22	973.02	174.49	220	799.30	19.30
23	972.00	182.42	230	790.34	20.34
24	970.95	190.35	240	781.35	21.35
25	969.91	198.28	250	772.37	22.37

V%	G_M	G_A	V_A	V_W	v
26	968.85	206.21	260	763.37	23.37
27	967.77	214.14	270	754.35	24.35
28	966.67	222.08	280	745.30	25.30
29	965.55	230.01	290	736.25	26.25
30	964.41	237.94	300	727.17	27.17
31	963.26	245.87	310	718.08	28.08
32	962.04	253.80	320	708.92	28.92
33	960.78	261.73	330	699.72	29.72
34	959.49	269.66	340	690.49	30.49
35	958.16	277.60	350	681.21	31.21
36	956.78	285.53	360	671.89	31.89
37	955.36	293.46	370	662.64	32.64
38	953.90	301.39	380	653.14	33.14
39	952.41	309.32	390	643.71	33.71
40	950.87	317.25	400	634.23	34.23
41	949.29	325.18	410	624.71	34.71
42	947.67	333.11	420	615.15	35.15
43	946.02	341.05	430	605.55	35.55
44	944.33	348.98	440	595.92	35.92
45	942.61	356.91	450	586.26	36.26
46	940.84	364.84	460	576.55	36.55
47	939.03	372.77	470	566.80	36.80
48	937.18	380.70	480	557.01	37.01
49	935.29	388.63	490	547.18	37.18
50	933.36	396.56	500	537.32	37.32
51	931.41	404.60	510	527.42	37.42
52	929.42	412.43	520	517.49	37.49
53	927.42	420.36	530	507.55	37.55
54	925.37	428.29	540	497.56	37.56
55	923.30	436.22	550	487.55	37.55
56	921.21	444.15	560	477.52	37.52
57	919.11	452.08	570	467.48	37.48
58	916.96	460.01	580	457.34	37.34
59	914.77	467.95	590	447.25	37.25
60	912.56	475.88	600	437.10	37.10
61	910.33	483.81	610	426.93	36.93
62	908.06	491.74	620	416.72	36.72
63	905.77	499.67	630	406.49	36.49

V%	G_M	G_A	V_A	V_W	v
64	903.47	507.60	640	396.25	36.25
65	901.15	515.53	650	385.99	35.99
66	898.81	523.46	660	375.71	35.71
67	896.43	531.40	670	365.38	35.38
68	894.03	539.33	680	355.04	35.04
69	891.59	547.26	690	344.66	34.66
70	889.14	555.19	700	334.27	34.27
71	886.66	563.12	710	323.85	33.85
72	884.14	571.05	720	313.39	33.39
73	881.59	578.98	730	302.90	32.90
74	879.03	586.92	740	292.39	32.39
75	876.44	594.85	750	281.86	31.86
76	873.81	602.78	760	271.29	31.29
77	871.15	610.71	770	260.69	30.69
78	868.46	618.64	780	250.06	30.06
79	865.73	626.57	790	239.38	29.38
80	862.97	634.50	800	228.69	28.68
81	860.17	642.43	810	217.95	27.95
82	857.35	650.37	820	207.18	27.18
83	854.49	658.30	830	196.38	26.38
84	851.58	666.23	840	185.53	25.53
85	848.63	674.16	850	174.64	24.64
86	845.61	682.09	860	163.68	23.68
87	842.55	690.02	870	152.68	22.68
88	839.44	697.95	880	141.63	21.63
89	836.27	705.88	890	130.52	20.52
90	833.02	713.82	900	119.31	19.31
91	829.69	721.75	910	108.04	18.04
92	826.26	729.68	920	96.63	16.63
93	822.72	737.61	930	85.19	15.19
94	819.05	745.54	940	73.58	13.58
95	815.25	753.47	950	61.84	11.84
96	811.28	761.40	960	49.93	9.93
97	807.15	769.33	970	37.86	7.86
98	802.79	777.27	980	25.54	5.54
99	798.12	785.20	990	12.93	2.93
100	793.13	793.13	1000	0.00	0.00

CHANGE IN DENSITY OF MIXTURES OF ETHYL ALCOHOL AND WATER WITH TEMPERATURE.

$g\%$ = gms. of alcohol in 100 gms. of mixture.

d_C = change in density per $°C$. difference in temp. from $15°C$.

d_F = change in density per $°F$. difference in temp. from $60°F$.

$g\%$	d_C	d_F	$g\%$	d_C	d_F	$g\%$	d_C	d_F	$g\%$	d_C	d_F
0	15	8	25	50	28	50	78	43	75	84	47
1	15	8	26	52	29	51	78	44	76	85	47
2	15	8	27	54	30	52	79	44	77	85	47
3	15	8	28	56	31	53	79	44	78	85	47
4	16	9	29	58	32	54	79	44	79	85	47
5	16	9	30	60	33	55	80	44	80	85	47
6	17	9	31	61	34	56	80	44	81	85	47
7	17	10	32	63	35	57	80	45	82	85	47
8	18	10	33	64	36	58	81	45	83	85	47
9	19	11	34	66	36	59	81	45	84	86	48
10	21	11	35	67	37	60	81	45	85	86	48
11	22	12	36	68	38	61	82	45	86	86	48
12	24	13	37	69	38	62	82	45	87	86	48
13	25	14	38	70	39	63	82	46	88	86	48
14	27	15	39	71	40	64	82	46	89	86	48
15	29	16	40	72	40	65	83	46	90	86	48
16	31	17	41	73	40	66	83	46	91	86	48
17	32	18	42	74	41	67	83	46	92	86	48
18	34	19	43	74	41	68	83	46	93	86	48
19	37	20	44	75	42	69	84	46	94	86	48
20	39	22	45	75	42	70	84	46	95	85	47
21	41	23	46	76	42	71	84	47	96	85	47
22	43	24	47	77	43	72	84	47	97	85	47
23	45	25	48	77	43	73	84	47	98	85	47
24	48	26	49	78	43	74	84	47	99	85	47
25	50	28	50	78	43	75	84	47	100	85	47

NOTE.—The values given in the above table for d_C and d_F must be divided by 10^5.

DILUTION OF ETHYL ALCOHOL AND WATER MIXTURES AT 60°F.

The figures given in the table represent the volumes of water which must be added to 100 volumes of mixtures of the percentage strengths shown at the side of the table to give mixtures of the percentage strengths shown at the head of the table.

Percentage by volume after dilution.

Original Percentage by volume	95.	90.	85.	80.	75.	70.	65.	60.	55.	50.	45.	40.	35.	30.	25.	20.	15.	10.	5.
100	6.51	13.26	20.55	28.59	37.58	47.75	59.38	72.85	88.63	107.46	130.28	158.56	194.63	242.39	308.95	408.59	574.64	907.22	1906.24
95		6.41	13.34	20.97	29.52	39.18	50.23	63.02	78.02	95.91	117.58	144.45	178.72	224.09	287.32	381.97	539.72	855.68	1804.74
90			6.56	13.80	21.89	31.05	41.51	53.63	67.84	84.79	105.32	130.77	163.27	206.22	266.12	355.80	505.25	804.57	1703.69
85				6.83	14.48	23.12	33.01	44.46	57.87	73.88	93.27	117.31	147.97	188.57	245.14	329.83	470.98	753.67	1602.84
80					7.20	16.33	24.64	35.41	48.04	63.00	81.36	103.98	132.84	171.04	224.29	304.00	436.84	702.91	1502.12
75						7.63	16.35	26.45	38.29	52.41	69.52	90.73	117.79	153.61	203.53	278.25	402.79	652.23	1401.49
70							8.14	17.57	28.62	41.80	57.77	77.56	102.82	136.25	182.84	252.58	368.82	601.63	1300.94
65								8.75	19.01	31.25	46.08	64.46	87.91	118.96	162.22	226.98	334.92	551.09	1200.46
60									9.47	20.77	34.46	51.43	73.07	101.72	141.68	201.07	301.07	500.62	1100.03
55										10.35	22.90	38.45	58.29	84.56	121.17	175.97	267.30	450.22	999.68
50											11.41	25.55	43.58	67.46	100.74	150.56	233.59	399.88	899.39
45												12.73	28.96	50.45	80.40	125.24	199.96	349.62	799.18
40													14.43	33.53	59.16	100.01	166.43	299.47	699.07
35														16.72	40.01	74.88	133.00	249.41	599.06
30															19.97	50.86	99.68	199.45	499.16
25																24.91	66.42	149.57	399.32
20																	33.21	99.73	299.53
15																		49.89	199.74
10																			99.90

SP. GR. OF ETHYL ALCOHOL—ETHER MIXTURES.

(F. Baker, *J. Chem. Soc.*, 1912, **101**, p. 1411.)

g = weight of ether in 100 gms. of mixture.

g	$S_{25°C, 4°C}$	g	$S_{25°C, 4°C}$	g	$S_{25°C, 4°C}$
0	0·788	40	0·760	70	0·736
10	0·781	50	0·752	80	0·728
20	0·774	50	0·752	90	0·718
30	0·767	60	0·744	100	0·708

Density of Mixtures of Methyl Alcohol and Water.

$g\%$ = wt. of methyl alcohol in 100 gms. of mixture.
$V\%$ = vol. of methyl alcohol in 100 vols. of mixture at 15°C.

Based on calculations made by the Bureau of Standards, Washington, from the results of Doroshevskii and Rozhdestvenskii (*J. Russ Phys. Chem. Soc.* **41**, pp. 977—996, 1909).

$g\%$	V%	$S_{15°C, 4°C}$	$g\%$	V%	$S_{15°C, 4°C}$	$g\%$	V%	$S_{15°C, 4°C}$	$g\%$	V%	$S_{15°C, 4°C}$
0	0.000	.99913	25	30.193	.96108	50	57.712	.91852	75	81.336	.86300
1	1.253	727	26	31.354	.95963	51	58.739	653	76	82.182	051
2	2.502	543	27	32.510	817	52	59.759	451	77	83.022	.85801
3	3.746	370	28	33.662	668	53	60.773	248	78	83.855	551
4	4.986	198	29	34.809	518	54	61.781	044	79	84.680	300
5	6.222	029	30	35.952	366	55	62.783	.90839	80	85.499	048
6	7.454	.98864	31	37.091	213	56	63.778	631	81	86.310	.84794
7	8.682	701	32	38.224	056	57	64.767	421	82	87.110	536
8	9.907	547	33	39.352	.94896	58	65.750	210	83	87.899	274
9	11.128	394	34	40.476	734	59	66.725	89996	84	88.677	009
10	12.345	241	35	41.594	570	60	67.693	781	85	89.448	.83742
11	13.559	093	36	42.708	404	61	68.654	563	86	90.212	475
12	14.770	97945	37	43.816	237	62	69.607	341	87	90.968	207
13	15.977	802	38	44.919	067	63	70.552	117	88	91.716	.82937
14	17.181	660	39	46.016	.93894	64	71.490	.88890	89	92.456	667
15	18.382	518	40	47.109	720	65	72.420	662	90	93.188	396
16	19.579	377	41	48.195	543	66	73.344	433	91	93.912	124
17	20.773	237	42	49.277	365	67	74.262	203	92	94.627	.81849
18	21.963	096	43	50.353	185	68	75.172	.87971	93	95.326	568
19	23.149	.96955	44	51.422	001	69	76.077	739	94	96.017	285
20	24.332	814	45	52.486	.92815	70	76.976	507	95	96.697	.80999
21	25.512	673	46	53.544	627	71	77.864	271	96	97.370	713
22	26.688	533	47	54.595	436	72	78.746	033	97	98.036	428
23	27.860	392	48	55.639	242	73	79.618	.86792	98	98.696	143
24	29.029	251	49	56.678	048	74	80.480	546	99	99.351	.79855
25	30.193	108	50	57.712	.91852	75	81.336	300	100	100.000	577

Specific Gravity of Aluminium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$ = grms. of Al_2Cl_6 in 100 grms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.00721	12	1.08902	23	1.17953	34	1.28080
2	1443	13	9684	24	8815	35	9046
3	2164	14	1.10466	25	9676	36	1.30066
4	2885	15	1248	26	1.20584	37	1086
5	3606	16	2073	27	1493	38	2106
6	4353	17	2897	28	2406	39	3126
7	5099	18	3721	29	3310	40	4146
8	5845	19	4545	30	4219	41	5224
9	6591	20	5370	31	5184		
10	7337	21	6231	32	6149		
11	8120	22	7092	33	7115		

Specific Gravity of Aluminium Sulphate Solutions

(Reuss, *Ber. Chem. Ges.*, 1884, **17**, 2888.)

$g\%$ = grms. of $Al_2(SO_4)_3$ in 100 grms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.0170	8	1.0870	15	1.1574	22	1.2274
2	270	9	968	16	668	23	375
3	370	10	1.1071	17	770	24	473
4	470	11	171	18	876	25	572
5	569	12	270	19	971		
6	670	13	369	20	1.2074		
7	768	14	467	21	168		

Specific Gravity of Ammonia Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 495.)

$g\%$ = gms. of $(NH_4)_2SO_4Al_2(SO_4)_324H_2O$.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
3	1.0141	9	1.0423
6	1.0282		

Specific Gravity of Ammonia Solutions at 15° C.

(Lunge and Wiernik, *Z. angew. Chem.*, 1889, **2**, 181.)

$g\%$ = grms. NH_3 in 100 grms. of solution
G = grms. NH_3 in 1 litre of solution.
C = Fall in Sp. Gr. for 1°C. rise in temperature.

$S\frac{15°C.}{15°C.}$	$g\%$	G.	C.	$S\frac{15°C.}{15°C.}$	$g\%$	G.	C.
1.000	0.00	0.0	0.00018	0.940	15.63	146.9	0.00039
0.998	0.45	4.5	0.0CC18	0.938	16.22	152.1	0.00040
0.996	0.91	9.1	0.00019	0.936	16.82	157.4	0.00041
0.994	1.37	13.6	0.00019	0.934	17.42	162.7	0.00041
0.992	1.84	18.2	0.00020	0.932	18.03	168.1	0.00042
0.990	2.31	22.9	0.00020	0.930	18.64	173.4	0.00042
0.988	2.80	27.7	0.00021	0.928	19.25	178.6	0.00043
0.986	3.30	32.5	0.00021	0.926	19.87	184.2	0.00044
0.984	3.80	37.4	0.00022	0.924	20.49	189.3	0.00045
0.982	4.30	42.2	0.00022	0.922	21.12	194.7	0.00046
0.980	4.80	47.0	0.00023	0.920	21.75	200.1	0.00047
0.978	5.30	51.8	0.00023	0.918	22.39	205.6	0.00048
0.976	5.80	56.6	0.00024	0.916	23.03	210.9	0.00049
0.974	6.30	61.4	0.00024	0.914	23.68	216.3	0.00050
0.972	6.80	66.1	0.00025	0.912	24.33	221.9	0.00051
0.970	7.31	70.9	0.00025	0.910	24.99	227.4	0.00052
0.968	7.82	75.7	0.00026	0.908	25.65	232.9	0.00053
0.966	8.33	80.5	0.00026	0.906	26.31	238.3	0.00054
0.964	8.84	85.2	0.00027	0.904	26.98	243.9	0.00055
0.962	9.35	89.9	0.00028	0.902	27.65	249.4	0.00056
0.960	9.91	95.1	0.00029	0.900	28.33	255.0	0.00057
0.958	10.47	100.3	0.00030	0.898	29.01	260.5	0.00058
0.956	11.03	105.4	0.00031	0.896	29.69	266.0	0.00059
0.954	11.60	110.7	0.00032	0.894	30.37	271.5	0.00060
0.952	12.17	115.9	0.00033	0.892	31.05	277.0	0.00060
0.950	12.74	121.0	0.00034	0.890	31.75	282.6	0.00061
0.948	13.31	126.2	0.00035	0.888	32.50	288.6	0.00062
0.946	13.88	131.3	0.00036	0.886	33.25	294.6	0.00063
0.944	14.46	136.5	0.00037	0.884	34.10	301.4	0.00064
0.942	15.04	141.7	0.00038	0.882	34.95	308.3	0.00065

Specific Gravity of Ammonia Chrome Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 497.)
$g\%$ = gms. of $(NH_4)_2SO_4Cr_2(SO_4)_3 24H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
4	1.0200	12	1.0610
8	1.0405		

Specific Gravity of Ammonia Iron Alum Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 496.)

$g\%$ = gms. of $(NH_4)_2SO_4Fe_2(SO_4)_3 24H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
5	1.023	25	1.122
10	.047	30	.148
15	.071	35	.175
20	.096	40	.203

Specific Gravity of Ammonium Acetate Solutions

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$ = grms. of CH_3COONH_4 in 100 grms. of solution.

$g\%$	$\dfrac{S_{16°C.}}{16°C.}$	$g\%$	$\dfrac{S_{16°C.}}{16°C.}$	$g\%$	$\dfrac{S_{16°C.}}{16°C.}$
3	1.008	20	1.042	37	1.0725
4	10	21	44	38	740
5	12	22	46	39	755
6	14	23	48	40	770
7	16	24	50	41	785
8	18	25	52	42	800
9	20	26	54	43	815
10	22	27	56	44	830
11	24	28	58	45	845
12	26	29	60	46	860
13	28	30	62	47	875
14	30	31	636	48	890
15	32	32	651	49	905
16	34	33	666	50	920
17	36	34	681	51	935
18	38	35	695	52	950
19	40	36	710		

Specific Gravity of Ammonium Carbonate Solutions.

(J. H. Smith, *J.S.C.I.*, 1883, **2**, 80.)

$g\%$ = gms. of dry commercial ammonium carbonate of composition NH_3 31.3%, CO_2 56.6%, H_2O 12.1% in 100 gms. of solution.

C = Fall in Sp. Gr. for 1°C. rise in temperature.

$g\%$	$S\frac{15°C.}{15°C.}$	C.	$g\%$	$S\frac{15°C.}{15°C.}$	C.
1.66	1.005	0.0002	23.78	1.080	0.0006
3.18	10	2	25.31	85	6
4.60	15	3	26.82	90	7
6.04	20	3	28.33	95	7
7.49	25	3	29.93	1.100	7
8.93	30	4	31.77	05	7
10.35	35	4	33.45	10	7
11.86	40	4	35.08	15	7
13.36	45	5	36.88	20	7
14.83	50	5	38.71	25	7
16.16	55	5	40.34	30	7
17.70	60	5	42.20	35	7
19.18	65	5	44.29	40	7
20.70	70	5	44.90	41	7
22.25	75	6			

Specific Gravity of Ammonium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$ = gms. of NH_4Cl in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.00316	10	1.03081	19	1.05648
2	0632	11	3370	20	5929
3	0948	12	3658	21	6204
4	1264	13	3947	22	6479
5	1580	14	4325	23	6754
6	1880	15	4524	24	7029
7	2180	16	4805	25	7304
8	2481	17	5086	26	7575
9	2781	18	5367		

Specific Gravity of Ammonium Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)

$g\% =$ gms. of NH_4NO_3 in 100 gms. of solution.

$g\%$	$S\dfrac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\dfrac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\dfrac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\dfrac{17\cdot5°C.}{17\cdot5°C.}$
1	1.0042	17	1.0729	33	1.1454	49	1.2249
2	085	18	773	34	502	50	300
3	127	19	816	35	550	51	353
4	170	20	860	36	598	52	407
5	212	21	905	37	646	53	460
6	255	22	950	38	694	54	514
7	297	23	995	39	742	55	567
8	340	24	1.1040	40	790	56	621
9	382	25	085	41	841	57	674
10	425	26	130	42	892	58	728
11	468	27	175	43	942	59	781
12	512	28	220	44	994	60	835
13	555	29	265	45	1.2045	61	888
14	599	30	310	46	096	62	942
15	642	31	358	47	147	63	1.3005
16	686	32	406	48	198	64	059

Sp. Gr. of Ammonium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 287.)

$g\% =$ gms. of $(NH_4)_2SO_4$ in 100 gms. of solution.

$g\%$	$S\dfrac{15°C.}{15°C.}$	$g\%$	$S\dfrac{15°C.}{15°C.}$	$g\%$	$S\dfrac{15°C.}{15°C.}$
1	1.0057	18	1.1035	35	1.2004
2	115	19	092	36	060
3	172	20	149	37	116
4	230	21	207	38	172
5	287	22	265	39	228
6	345	23	323	40	284
7	403	24	381	41	343
8	460	25	439	42	402
9	518	26	496	43	462
10	575	27	554	44	522
11	632	28	612	45	583
12	690	29	670	46	644
13	747	30	724	47	705
14	805	31	780	48	766
15	862	32	836	49	828
16	920	33	892	50	890
17	977	34	948		

Specific Gravity of Arsenic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 316.)

$g\%$ = gms. of H_3AsO_4 in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.006	32	1.248	62	1.626
2	13	33	57	63	43
3	19	34	67	64	59
4	26	35	77	65	75
5	32	36	88	66	93
6	39	37	99	67	1.712
7	46	38	1.309	68	30
8	52	39	20	69	49
9	59	40	31	70	67
10	66	41	42	71	88
11	73	42	53	72	1.809
12	81	43	66	73	30
13	88	44	76	74	51
14	96	45	87	75	72
15	1.103	46	1.400	76	97
16	11	47	12	77	1.921
17	19	48	25	78	46
18	26	49	37	79	70
19	34	50	50	80	95
20	42	51	64	81	2.020
21	50	52	78	82	45
22	58	53	91	83	70
23	67	54	1.505	84	95
24	75	55	19	85	2.120
25	83	56	34	86	49
26	92	57	49	87	78
27	1.201	58	64	88	2.207
28	10	59	79	89	36
29	19	60	94	90	65
30	28	61	1.610	91	95
31	38				

Specific Gravity of Barium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$ = gms. of $BaBr_2$ in 100 gms. of solution.

$g\%$	$S\frac{19·5°C.}{19·5°C.}$	$g\%$	$S\frac{19·5°C.}{19·5°C.}$	$g\%$	$S\frac{19·5°C.}{19·5°C.}$
5	1.045	25	1.262	45	1.580
10	.092	30	.329	50	.685
15	.144	35	.405	55	.800
20	.201	40	.485		

Specific Gravity of Barium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\% = $ gms. of $\frac{CH_3COO}{CH_3COO}{>}Ba$ in 100 gms. of solution.

$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$
1	1.0087	15	1.1120	29	1.2312
2	174	16	201	30	402
3	261	17	282	31	512
4	348	18	363	32	622
5	436	19	444	33	732
6	500	20	522	34	842
7	564	21	608	35	954
8	628	22	694	36	1.3075
9	692	23	780	37	196
10	758	24	866	38	317
11	830	25	952	39	438
12	902	26	1.2042	40	558
13	974	27	132		
14	1.1046	28	222		

Specific Gravity of Barium Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 283.)

$g\% = $ gms. of $BaCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.00917	10	1.09508	19	1.19458
2	1834	11	1.10576	20	1.20611
3	2750	12	1643	21	1892
4	3667	13	2711	22	3173
5	4584	14	3778	23	4455
6	5569	15	4846	24	5736
7	6554	16	5999	25	7017
8	7538	17	7152		
9	8523	18	8305		

Specific Gravity of Barium Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$ = gms. of BaI_2 in 100 gms. of solution.

$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$	$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$	$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$
5	1.045	25	1.265	45	1.596
10	.091	30	.333	50	.704
15	.143	35	.412	55	.825
20	.201	40	.495	60	.970

Specific Gravity of Borax Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 473.)

$g\%$ = gms. of $Na_2B_4O_7,10H_2O$ in 100 gms. of solution.
$G\%$ = gms. of $Na_2B_4O_7$ in 100 gms. of solution.

$g\%$	$G\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$G\%$	$S\frac{15°C.}{15°C.}$
1	0.5288	1.0049	4	2.1152	1.0199
2	1.0576	099	5	2.6439	249
3	1.5864	149	6	3.1727	299

Specific Gravity of Boric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 473.)

$g\%$ = gms. of H_3BO_3 in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.0034	3	1.0106
2	1.0069	4	1.0147

Specific Gravity of Cadmium Bromide Solutions.

(Gerlach, *Z. anal. Chem.,* 1869, **8**, 285.)

$g\%$ = gms. of $CdBr_2$ in 100 gms. of solution.

$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$
5	1.043	25	1.260	45	1.578
10	.090	30	.326	50	.680
15	.141	35	.400		
20	.199	40	.481		

Specific Gravity of Cadmium Chloride Solutions.

(Gerlach, *Z. anal. Chem.,* 1869, **8**, 283.)

$g\%$ = gms. of $CdCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$
5	1.045	35	1.396
10	1.089	40	1.472
15	1.140	45	1.561
20	1.195	50	1.656
25	1.256	55	1.765
30	1.321	60	1.890

Special Gravity of Cadmium Iodide Solutions.

(Gerlach, *Z. anal. Chem.,* 1869, **8**, 285.)

$g\%$ = gms. of CdI_2 in 100 gms. of solution.

$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$
5	1.044	25	1.253	45	1.575
10	.088	30	.319	50	.680
15	.138	35	.395		
20	.194	40	.476		

Specific Gravity of Calcium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\% =$ gms. of $\genfrac{}{}{0pt}{}{CH_3COO}{CH_3COO}{>}Ca$ in 100 gms. of solution.

$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$
1	1.0051	11	1.0582	21	1.1105
2	103	12	634	22	159
3	155	13	686	23	213
4	207	14	739	24	267
5	260	15	792	25	321
6	313	16	843	26	375
7	367	17	895	27	430
8	421	18	947	28	484
9	475	19	999	29	539
10	530	20	1.1051	30	594

Specific Gravity of Calcium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\% =$ gms. of $CaBr_2$ in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$	$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$	$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$
5	1.044	25	1.252	45	1.549
10	.089	30	.315	50	.641
15	.139	35	.385		
20	.194	40	.461		

Density of Calcium Chloride Solutions.

(Pickering, 1894.)

$g\% =$ gms. of $CaCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{17\cdot9°C.}{4°C.}$	$g\%$	$S\frac{17\cdot9°C.}{4°C.}$	$g\%$	$S\frac{17\cdot9°C.}{4°C}$
1	1.007	17	1.150	31	1.294
3	24	19	69	33	1.316
5	41	21	89	35	38
7	58	23	1.209	37	61
9	76	25	29	39	84
11	94	27	50	41	1.406
13	1.112	29	72	43	29
15	31				

Specific Gravity of Chromic Acid Solutions.

(Zettnow, *Pogg. Ann.*, 1871, **143**, 474.)
$g\%$ = gms. of CrO_3 in 100 gms. of solution.

$g\%$	$S\frac{19°C.}{4°C.}$	$g\%$	$S\frac{19°C.}{4°C.}$
8.25	1.059	31.8	1.203
8.8	.067	32.6	.219
12.3	.096	37.8	.345
19.3	.157	62.2	.702

Specific Gravity of Chromium Sulphate Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 494.)
$g\%$ = gms. of $Cr_2(SO_4)_3$ in 100 gms. of solution.

Violet modification.		Green modification.	
$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
2.74	1.0275	5.48	1.0510
5.48	.0560	10.96	.1070
10.96	.1150	16.44	.1680
16.44	.1785	21.92	.2340
21.92	.2480	27.40	.3055
27.40	.3250	32.88	.3825
		38.36	.4650
		43.84	.5530

Specific Gravity of Citric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 295.)
$g\%$ = gms. of $C_6O_7H_8, H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
2	1.0074	26	1.1060	50	1.2204
4	149	28	152	52	307
6	227	30	244	54	410
8	309	32	333	56	514
10	392	34	422	58	627
12	470	36	515	60	738
14	549	38	612	62	849
16	632	40	709	64	960
18	718	42	814	66	1.3071
20	805	44	899		
22	889	46	998		
24	972	48	1.2103		

Specific Gravity of Cobalt Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$ = gms. of $CoCl_2$ in 100 gms. of solution.

$g\%$	$S\dfrac{17.5°C}{17.5°C}$	$g\%$	$S\dfrac{17.5°C}{17.5°C}$	$g\%$	$S\dfrac{17.5°C}{17.5°C}$
1	1.0099	10	1.0997	18	1.1977
2	198	11	1.1112	19	1.2110
3	297	12	228	20	245
4	396	13	344	21	396
5	496	14	460	22	547
6	595	15	579	23	698
7	695	16	711	24	849
8	795	17	844	25	1.3002
9	895				

Specific Gravity of Copper Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$ = gms. of $CuCl_2$ in 100 gms. of solution.

$g\%$	$S\dfrac{17.5°C}{17.5°C}$	$g\%$	$S\dfrac{17.5°C}{17.5°C}$	$g\%$	$S\dfrac{17.5°C}{17.5°C}$	$g\%$	$S\dfrac{17.5°C}{17.5°C}$
1	1.0091	11	1.1049	21	1.2362	31	1.3784
2	182	12	178	22	501	32	950
3	273	13	307	23	640	33	1.4116
4	364	14	436	24	779	34	287
5	455	15	565	25	918	35	447
6	548	16	696	26	1.3058	36	615
7	641	17	827	27	198	37	782
8	734	18	958	28	338	38	949
9	827	19	1.2089	29	478	39	1.5116
10	920	20	223	30	618	40	284

Specific Gravity of Copper Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)
$g\%$ = gms. of $Cu(NO_3)_2$ in 100 gms. of solution.

$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$
1	1.0090	13	1.1242	25	1.2644	37	1.4274
2	180	14	342	26	775	38	424
3	270	15	442	27	906	39	574
4	360	16	561	28	1.3057	40	724
5	452	17	680	29	168	41	894
6	550	18	799	30	299	42	1.5064
7	648	19	918	31	432	43	234
8	746	20	1.2037	32	575	44	404
9	844	21	158	33	708	45	576
10	942	22	279	34	841		
11	1.1042	23	400	35	974		
12	142	24	521	36	1.4124		

Specific Gravity of Copper Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)
$G\%$ = gms. $CuSO_4 5H_2O$ in 100 gms. of solution.
$g\%$ = gms. of $CuSO_4$ in 100 gms. of solution.

$G\%$	$g\%$	$S\frac{18°C.}{18°C.}$	$G\%$	$g\%$	$S\frac{18°C.}{18°C.}$
1	0.64	1.0063	16	10.23	1.1063
2	1.28	126	17	10.87	135
3	1.92	190	18	11.51	208
4	2.56	254	19	12.15	281
5	3.20	319	20	12.79	354
6	3.84	384	21	13.42	427
7	4.48	450	22	14.06	501
8	5.11	516	23	14.70	585
9	5.75	582	24	15.34	659
10	6.39	649	25	15.98	738
11	7.03	716	26	16.62	817
12	7.67	785	27	17.26	898
13	8.31	854	28	17.90	980
14	8.95	923	29	18.54	1.2063
15	9.59	993	30	19.18	146

NOTE.—Accurate values for density at 25°C. and 40°C. of solutions of copper sulphate containing various percentages of sulphuric acid (copper-plating baths, etc.) are given by Holler and Peffer, *J. Amer. Chem. Soc.*, 1916, **38**, 1021.

Density of Dextrose Solutions.

(Jackson, *Bull. Bureau of Standards*, 1916, **13**, 633, at 20°C.; Tollens, *Berichte*, 1896, **9**, 1537, at 17·5°C.)

$g\%$ = gms. of dextrose in 100 gms. of solution.

$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{17.5°C.}{4°C.}$
4	1.01378	18	1.07116	10	1.037
6	.02164	20	.07981	20	.080
8	.02961	22	.08857	30	.126
10	.03769	24	.09744	40	.173
12	.04589	26	.10643	50	.222
14	.05420	28	.11553	60	.273
16	.06262	30	.12475	70	.325
				80	.378

Specific Gravity of Ferric Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)

$g\%$ = gms. of $FeCl_3$ in 100 gms. of solution.

$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$
1	1.008	21	1.191	41	1.428
2	16	22	1.202	42	41
3	25	23	12	43	54
4	33	24	23	44	69
5	42	25	34	45	81
6	51	26	45	46	94
7	60	27	56	47	1.507
8	69	28	68	48	20
9	78	29	80	49	33
10	87	30	92	50	47
11	95	31	1.304	51	60
12	1.104	32	16	52	73
13	13	33	28	53	87
14	23	34	40	54	1.600
15	31	35	52	55	12
16	40	36	64	56	24
17	50	37	76	57	36
18	60	38	90	58	48
19	70	39	1.403	59	59
20	80	40	15	60	70

Specific Gravity of Ferric Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)
$g\% = $ gms. of $Fe_2(NO_3)_2$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{7\cdot5°C.}}{17\cdot5°C.}$
1	1.0080	18	1.1440	35	1.3164	52	1.5272
2	160	19	526	36	280	53	422
3	240	20	612	37	396	54	572
4	320	21	712	38	512	55	722
5	398	22	812	39	628	56	892
6	472	23	912	40	746	57	1.6062
7	546	24	1.2012	41	864	58	232
8	620	25	110	42	982	59	402
9	694	26	212	43	1.4100	60	572
10	770	27	314	44	218	61	764
11	852	28	416	45	338	62	956
12	934	29	518	46	465	63	1.7148
13	1.1016	30	622	47	592	64	340
14	098	31	730	48	719	65	532
15	182	32	838	49	846		
16	268	33	946	50	972		
17	354	34	1.3054	51	1.5122		

Specific Gravity of Ferric Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 308.)
$g\% = $ gms. of $Fe_2(SO_4)_3$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{18°C.}}{18°C.}$	$g\%$	$\dfrac{S_{18°C.}}{18°C.}$	$g\%$	$\dfrac{S_{18°C.}}{18°C.}$	$g\%$	$\dfrac{S_{18°C.}}{18°C.}$
1	1.008	12	1.118	23	1.245	34	1.395
2	17	13	29	24	58	35	1.411
3	27	14	40	25	71	36	27
4	36	15	51	26	84	37	42
5	46	16	62	27	97	38	58
6	57	17	73	28	1.310	39	74
7	67	18	84	29	23	40	90
8	77	19	96	30	37	41	1.506
9	87	20	1.208	31	51	42	23
10	97	21	20	32	65	43	40
11	1.107	22	32	33	80	44	57

Specific Gravity of Ferrous Ammonium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of $FeSO_4(NH_4)_2SO_46H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{19°C.}}{19°C.}$	$g\%$	$\dfrac{S_{19°C.}}{19°C.}$	$g\%$	$\dfrac{S_{19°C.}}{19°C.}$	$g\%$	$\dfrac{S_{19°C.}}{19°C.}$
1	1.006	9	1.054	17	1.104	25	1.156
2	13	10	60	18	10	26	64
3	18	11	66	19	16	27	71
4	24	12	73	20	24	28	79
5	30	13	80	21	30	29	85
6	36	14	85	22	36	30	93
7	42	15	92	23	43		
8	47	16	97	24	50		

Specific Gravity of Ferrous Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$G\%$ = gms. of $FeSO_47H_2O$ in 100 gms. of solution.

$g\%$ = gms. of $FeSO_4$ in 100 gms. of solution.

$G\%$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$G\%$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	0.55	1.005	21	11.48	1.118
2	1.09	11	22	12.03	25
3	1.64	16	23	12.58	31
4	2.19	21	24	13.12	37
5	2.73	27	25	13.67	43
6	3.28	32	26	14.22	49
7	3.83	37	27	14.76	55
8	4.37	43	28	15.31	61
9	4.72	48	29	15.86	68
10	5.47	54	30	16.40	74
11	6.01	59	31	16.95	80
12	6.56	65	32	17.50	87
13	7.11	71	33	18.04	93
14	7.65	77	34	18.59	1.200
15	8.20	82	35	19.14	06
16	8.75	88	36	19.68	13
17	9.30	94	37	20.23	19
18	9.84	1.100	38	20.78	26
19	10.39	06	39	21.32	32
20	10.94	12	40	21.87	39

Specific Gravity of Formaldehyde Solutions.

(Davis, *J.S. Chem. Ind.*, 1897, **16**, 502.)

$g\%$ = gms. of HCHO in 100 gms. of solution

$g\%$	$S\frac{60°F.}{4°C.}$	$g\%$	$S\frac{60°F.}{4°C.}$	$g\%$	$S\frac{60°F.}{4°C.}$	$g\%$	$S\frac{60°F.}{4°C.}$
5	1.015	15	1.037	25	1.066	35	1.103
10	24	20	52	30	82	40	24

Density of Formic Acid Solutions.

(Richardson and Kramer, *Ber. Chem. Ges.*, 1874, **7**, 1495, and 1876, **9**, 1929.)

$g\%$ = gms. of HCOOH in 100 gms. of solution.

$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{20°C.}{4°C.}$
1	1.0020	38	1.0920	80	1.1861
2	045	42	1.1016	82	897
4	094	46	109	84	930
6	1.0142	50	208	86	977
8	197	54	296	88	1.2013
10	247	58	382	90	045
14	346	62	474	92	079
18	442	66	566	94	118
22	538	70	656	96	159
26	634	74	753	98	184
30	730	78	819	100	213
34	824				

C

Specific Gravity of Mixtures of Glycerin and Water.

(Skalweit, *Repertor. d. Analyt. Chemie.*, 1885, **5**, 18.)

$g\%$ = gms. of glycerin in 100 gms. of mixture.

$g\%$	$\dfrac{S\,15^\circ C.}{15^\circ C.}$	$g\%$	$\dfrac{S\,15^\circ C.}{15^\circ C.}$	$g\%$	$\dfrac{S\,15^\circ C.}{15^\circ C.}$	$g\%$	$\dfrac{S\,15^\circ C.}{15^\circ C.}$
0	1.0000	26	1.0646	51	1.1318	76	1.2017
1	024	27	672	52	346	77	044
2	048	28	698	53	374	78	071
3	072	29	724	54	402	79	098
4	096	30	750	55	430	80	125
5	120	31	777	56	458	81	152
6	144	32	804	57	486	82	179
7	168	33	831	58	514	83	206
8	192	34	858	59	542	84	233
9	216	35	885	60	570	85	260
10	240	36	912	61	599	86	287
11	265	37	939	62	628	87	314
12	290	38	966	63	657	88	341
13	315	39	993	64	686	89	368
14	340	40	1.1020	65	715	90	395
15	365	41	047	66	743	91	421
16	390	42	074	67	771	92	447
17	415	43	101	68	799	93	473
18	440	44	128	69	827	94	499
19	465	45	155	70	855	95	525
20	490	46	182	71	882	96	550
21	516	47	209	72	909	97	575
22	542	48	236	73	936	98	600
23	568	49	263	74	963	99	625
24	594	50	290	75	990	100	650
25	620						

Density of Hydriodic Acid Solutions.

(Perkin, *Journ. Chem. Soc.*, 1889, **55**, 680.)

$g\%$ = gms. of HI in 100 gms. of solution.

$g\%$	$\dfrac{S\,15^\circ C.}{4^\circ C.}$	$g\%$	$\dfrac{S\,15^\circ C.}{4^\circ C.}$
20.77	1.1758	56.78	1.6998
31.77	1.2962	61.97	1.8218
42.7	1.4489		

Specific Gravity of Hydrobromic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 316.)

$g\%$ = gms. of HBr in 100 gms. of solution.

$g\%$	$S\dfrac{14°C.}{14°C.}$	$g\%$	$S\dfrac{14°C.}{14°C.}$	$g\%$	$S\dfrac{14°C.}{14°C.}$	$g\%$	$S\dfrac{14°C.}{14°C.}$	$g\%$	$S\dfrac{14°C.}{14°C.}$
1	1.007	11	1.081	21	1.167	31	1.268	41	1.389
2	1.014	12	1.089	22	1.176	32	1.279	42	1.403
3	1.021	13	1.097	23	1.186	33	1.290	43	1.417
4	1.028	14	1.106	24	1.196	34	1.302	44	1.431
5	1.035	15	1.114	25	1.206	35	1.314	45	1.445
6	1.043	16	1.122	26	1.215	36	1.326	46	1.459
7	1.050	17	1.131	27	1.225	37	1.338	47	1.473
8	1.058	18	1.140	28	1.235	38	1.351	48	1.487
9	1.065	19	1.149	29	1.246	39	1.363	49	1.502
10	1.073	20	1.158	30	1.257	40	1.376		

Density of Hydrochloric Acid Solutions.

(Lunge and Marchlewski *Z. angew. Chem.*, 1891, **4**, 133.)

$g\%$ = gms. of HCl in 100 gms. of solution.

G = gms. of HCl in 1 litre of solution.

$S\dfrac{15°C.}{4°C.}$	$g\%$	G.	$S\dfrac{15°C.}{4°C.}$	$g\%$	G.
1.000	0.16	1.6	1.105	20.97	232
1.005	1.15	12	1.110	21.92	243
1.010	2.14	22	1.115	22.86	255
1.015	3.12	32	1.120	23.82	267
1.020	4.13	42	1.125	24.78	278
1.025	5.15	53	1.130	25.75	291
1.030	6.15	64	1.135	26.70	303
1.035	7.15	74	1.140	27.66	315
1.040	8.16	85	1.145	28.61	328
1.045	9.16	96	1.150	29.57	340
1.050	10.17	107	1.155	30.55	353
1.055	11.18	118	1.160	31.52	366
1.060	12.19	129	1.165	32.49	379
1.065	13.19	141	1.170	33.46	392
1.070	14.17	152	1.175	34.42	404
1.075	15.16	163	1.180	35.39	418
1.080	16.15	174	1.185	36.31	430
1.085	17.13	186	1.190	37.23	443
1.090	18.11	197	1.195	38.16	456
1.095	19.06	209	1.200	39.11	469
1.100	20.01	220			

Change in Density of Hydrochloric Acid Solutions with Temperature.

$g\%$ = gms. of HCl in 100 gms. of solution.
C = change in density per °C. at room temperature.

$g\%$	C.	$g\%$	C.	$g\%$	C.
5	0.0001	20	0.0004	35	0.0006
10	0.0002	25	0.0005	40	0.0007
15	0.0003	30	0.0006		

Density of Hydrofluoric Acid Solutions.

(Hill and Sirkar, *Proc. Roy. Soc.*, 1909, A, **83**, 130.)

$g\%$ = gms. of HF in 100 gms. of solution.

$g\%$	$S\frac{0°C.}{4°C.}$	$g\%$	$S\frac{0°C.}{4°C.}$	$g\%$	$S\frac{0°C.}{4°C.}$
6.1	1.028	56.7	1.230	88.7	1.208
12.1	1.047	63.2	1.247	91.0	1.164
21.4	1.085	73.8	1.261	95.0	1.082
28.4	1.110	76.9	1.262	100.0	1.0005
45.3	1.172	85.1	1.232		

Specific Gravity of Hydrofluosilicic Acid.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 316.)

$g\%$ = gms. of H_2SiF_6 in 100 gms. of solution.

$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$	$g\%$	$S\frac{17.5°C.}{17.5°C.}$
2	1.0161	14	1.1190	26	1.2335
4	324	16	373	28	537
6	491	18	559	30	742
8	661	20	748	32	951
10	834	22	941	34	1.3162
12	1.1011	24	1.2136		

Specific Gravity of Lead Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $(CH_3COO)_2Pb3H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.0064	18	1.1234	35	1.2669
2	127	19	309	36	768
3	191	20	384	37	867
4	255	21	464	38	966
5	319	22	544	39	1.3064
6	386	23	624	40	163
7	453	24	704	41	269
8	520	25	784	42	376
9	587	26	869	43	482
10	654	27	955	44	588
11	725	28	1.2040	45	695
12	796	29	126	46	810
13	867	30	211	47	925
14	939	31	303	48	1.4041
15	1.1010	32	395	49	156
16	084	33	486	50	271
17	159	34	578		

Specific Gravity of Lead Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of $Pb(NO_3)_2$ in 100 gms. of solution.

$g\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$S\frac{17·5°C.}{17·5°C.}$
1	1.0080	11	1.0963	21	1.2016	31	1.3276
2	163	12	1.1059	22	132	32	416
3	247	13	157	23	251	33	558
4	331	14	257	24	372	34	702
5	416	15	359	25	495	35	848
6	502	16	463	26	620	36	996
7	591	17	569	27	747	37	1.4146
8	682	18	677	28	876		
9	775	19	788	29	1.3007		
10	869	20	902	30	140		

Specific Gravity of Magnesium Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$ = gms. of $MgBr_2$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$
5	1.043	25	1.247	40	1.451
10	1.087	30	1.310	45	1.535
15	1.137	35	1.377	50	1.625
20	1.191				

Specific Gravity of Magnesium Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$ = gms. of $MgCl_2$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.00844	13	1.11300	25	1.22737
2	1689	14	2203	26	3777
3	2533	15	3106	27	4817
4	3378	16	4045	28	5857
5	4222	17	4984	29	6897
6	5096	18	5922	30	7937
7	5970	19	6861	31	9029
8	6844	20	7800	32	1.30121
9	7718	21	8787	33	1213
10	8592	22	9775	34	2305
11	9495	23	1.20762	35	3397
12	1.10398	24	1750		

Specific Gravity of Magnesium Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 258.)

$g\%$ = gms. of MgI_2 in 100 gms. of solution.

$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$
5	1.043	25	1.254	45	1.568
10	1.088	30	1.320	50	1.668
15	1.139	35	1.395	55	1.780
20	1.194	40	1.474	60	1.915

Density of Magnesium Sulphate Solutions.

(Barnes and Scott, *Journ. Phys. Chem.*, 1898, **2**, 536.)

$g\%$ = gms. of $MgSO_4$ in 100 gms. of solution.

$g\%$	$S_{\frac{18\cdot2°C.}{4°C.}}$	$g\%$	$S_{\frac{18\cdot2°C.}{4°C.}}$
2.01	1.0187	18.41	1.1950
8.08	1.0803	21.60	1.2330
11.29	1.1147	24.53	1.2693
12.63	1.1292	25.91	1.2860
13.79	1.1423	26.25	1.2903

Specific Gravity of Manganese Chloride Solutions

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 476.)

$g\%$ = gms. of $MnCl_2$ in 100 gms. of solution.

$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$
5	1.045	20	1.189	35	1.372
10	1.091	25	1.245	40	1.443
15	1.138	30	1.306	45	1.514

Specific Gravity of Manganese Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 478.)

$g\%$ = gms. of $MnSO_4$ in 100 gms. of solution.

$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$
5	1.0500	15	1.1605	25	1.2870
10	1.1035	20	1.2215	30	1.3575

Density of Mercuric Chloride Solution.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)
$g\%$ = gms. of $HgCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$
1	1.0072	8	1.071
2	148	9	81
3	236	10	96
4	323	11	1.103
5	411	12	15
		13	27
(From Schröder's values.)		(From Mendelejeff's values.)	

Specific Gravity of Nickel Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 306.)
$g\%$ = gms. of $NiCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$S\frac{17·5°C}{17·5°C}$
1	1.0099	10	1.0997	18	1.1977
2	198	11	1.1112	19	1.2110
3	297	12	228	20	245
4	396	13	344	21	396
5	496	14	460	22	547
6	595	15	579	23	698
7	695	16	711	24	849
8	795	17	844	25	1.3002
9	895				

Density of Nickel Sulphate Solutions.

(MacGregor, *Trans. Can.*, 1890, **8**, 19.)
and (Klein, *Wied. Ann.*, 1886, **27**, 151.)
$g\%$ = gms. of $NiSO_4$ in 100 gms. of solution.

$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$
1.251	1.01155	7.46	1.0379
2.080	1.02046	14.38	1.0759
3.963	1.04064	26.91	1.1503
		38.00	1.2219

Density of Nitric Acid Solutions.

(Lunge and Keane, " Technical Methods of Chemical Analysis," 1908, Vol. I, p. 325.)

$g\%$ = gms. of HNO_3 in 100 gms. of solution.
G = gms. of HNO_3 in 1 litre of solution.

$S\frac{15°C.}{4°C.}$	$g\%$	G.	$S\frac{15°C.}{4°C.}$	$g\%$	G.
1.000	0.10	1	1.170	27.88	326
1.005	1.00	10	1.175	28.63	336
1.010	1.90	19	1.180	29.38	347
1.015	2.80	28	1.185	30.13	357
1.020	3.70	38	1.190	30.88	367
1.025	4.60	47	1.195	31.62	378
1.030	5.50	57	1.200	32.36	388
1.035	6.38	66	1.205	33.09	399
1.040	7.26	75	1.210	33.82	409
1.045	8.13	85	1.215	34.55	420
1.050	8.99	94	1.220	35.28	430
1.055	9.84	104	1.225	36.03	441
1.060	10.68	113	1.230	36.78	452
1.065	11.51	123	1.235	37.53	463
1.070	12.33	132	1.240	38.29	475
1.075	13.15	141	1.245	39.05	486
1.080	13.95	151	1.250	39.82	498
1.085	14.74	160	1.255	40.58	509
1.090	15.53	169	1.260	41.34	521
1.095	16.32	179	1.265	42.10	533
1.100	17.11	188	1.270	42.87	544
1.105	17.89	198	1.275	43.64	556
1.110	18.67	207	1.280	44.41	568
1.115	19.45	217	1.285	45.18	581
1.120	20.23	227	1.290	45.95	593
1.125	21.00	236	1.295	46.72	605
1.130	21.77	246	1.300	47.49	617
1.135	22.54	256	1.305	48.26	630
1.140	23.31	266	1.310	49.07	643
1.145	24.08	276	1.315	49.89	656
1.150	24.84	285	1.320	50.71	669
1.155	25.60	296	1.325	51.53	683
1.160	26.36	306	1.330	52.37	697
1.165	27.12	316	1.335	53.22	710

$\frac{S_{15°C.}}{4°C.}$	$g\%$	G.	$\frac{S_{15°C.}}{4°C.}$	$g\%$	G.
1.340	54.07	725	1.475	84.45	1246
1 345	54.93	739	1.480	86.05	1274
1.350	55.79	753	1.485	87.70	1302
1.355	56.66	768	1.490	89.60	1335
1.360	57.57	783	1.495	91.60	1369
1.365	58.48	798	1.500	94.09	1411
1.370	59.39	814	1.501	94.60	1420
1.375	60.30	829	1.502	95.08	1428
1.380	61.27	846	1.503	95.55	1436
1.385	62.24	862	1.504	96.00	1444
1.390	63.23	879	1.505	96.39	1451
1.395	64.25	896	1.506	96.76	1457
1.400	65.30	914	1.507	97.13	1464
1.405	66.40	933	1.508	97.50	1470
1.410	67.50	952	1.509	97.84	1476
1.415	68.63	971	1.510	98.10	1481
1.420	69.80	991	1.511	98.32	1486
1.425	70.98	1011	1.512	98.53	1490
1.430	72.17	1032	1.513	98.73	1494
1.435	73.39	1053	1.514	98.90	1497
1.440	74.68	1075	1.515	99.07	1501
1.445	75.98	1098	1.516	99.21	1504
1.450	77.28	1121	1.517	99.34	1507
1.455	78.60	1144	1.518	99.46	1510
1.460	79.98	1168	1.519	99.57	1512
1.465	81.42	1193	1.520	99.67	1515
1.470	82.90	1219			

Change in Density of Nitric Acid with Temperature.

(Lunge and Keane, *loc. cit.*, p. 327.)

S = approximate specific gravity.

C = fall in density per °C. rise in temperature in the neighbourhood of 15°C.

$$\frac{S_{15°C.}}{4°C.} = S\frac{t°C}{4°} + C (t - 15)$$

S.	C.	S.	C.
1.000 to 1.020	0.0001	1.281 to 1.310	0.0010
1.021 ,, 1.040	2	1.311 ,, 1.350	11
1.041 ,, 1.070	3	1.351 ,, 1.365	12
1.071 ,, 1.100	4	1.366 ,, 1.400	13
1.101 ,, 1.130	5	1.401 ,, 1.435	14
1.131 ,, 1.161	6	1.436 ,, 1.490	15
1.162 ,, 1.200	7	1.491 ,, 1.500	16
1.201 ,, 1.245	8	1.501 ,, 1.520	17
1.246 ,, 1.280	9		

Influence of Nitrogen Peroxide on Density of Nitric Acid.

Bousfield (*J.C.S.*, 1919, 48) and Pascal and Garnier (*Bull. soc. Chim.*, 1919, **25**, 309), who worked by adding liquid N_2O_4 to nitric acid (of $S\frac{18}{4}$ 1·5126 and $S\frac{15}{4}$ 1·5130 respectively), both agree in making the increase in specific gravity ·0040 per 1% N_2O_4 in the mixture for concentrations 5% to 20% N_2O_4 and about ·0035 per 1% N_2O_4 for concentrations lower than 5%. Lunge and Marchlewski, who used acid of $S\frac{15}{4}$ 1·490 and estimated the N_2O_4 in it by titration, give corrections increasing from ·0030 per 1% N_2O_4, at a concentration of 1%, to ·0066 per 1% at concentrations 5% to 12·5%.

Specific Gravity of Oxalic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 315.)

$g\%$ = gms. of $C_2H_2O_4.2H_2O$ in 100 gms. of solution.

$g\%$	$\frac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\frac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\frac{S_{17\cdot5°C.}}{17\cdot5°C.}$
1	1.0035	5	1.0175	9	1.0315
2	070	6	210	10	350
3	105	7	245	11	385
4	140	8	280	12	420

Specific Gravity of Phosphoric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 292.)

$g\%$ = gms. of H_3PO_4 in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.0054	21	1.1262	41	1.2731
2	1.0109	22	1.1329	42	1.2812
3	1.0164	23	1.1397	43	1.2894
4	1.0220	24	1.1465	44	1.2976
5	1.0276	25	1.1534	45	1.3059
6	1.0333	26	1.1604	46	1.3143
7	1.0390	27	1.1674	47	1.3227
8	1.0449	28	1.1745	48	1.3313
9	1.0508	29	1.1817	49	1.3399
10	1.0567	30	1.1889	50	1.3486
11	1.0627	31	1.1962	51	1.3573
12	1.0688	32	1.2036	52	1.3661
13	1.0749	33	1.2111	53	1.3750
14	1.0811	34	1.2186	54	1.3840
15	1.0874	35	1.2262	55	1.3931
16	1.0937	36	1.2338	56	1.4022
17	1.1001	37	1.2415	57	1.4114
18	1.1065	38	1.2493	58	1.4207
19	1.1130	39	1.2572	59	1.4301
20	1.1196	40	1.2651	60	1.4395

Specific Gravity of Potash Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 307.)

$g\%$ = gms. of $K_2SO_4Al_2(SO_4)_3 24H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{17·5°C.}}{17·5°C.}$	$g\%$	$\dfrac{S_{17·5°C.}}{17·5°C.}$	$g\%$	$\dfrac{S_{17·5°C.}}{17·5°C.}$
1	1.0049	6	1.0310	10	1.0523
2	100	7	362	11	578
3	152	8	415	12	635
4	205	9	469	13	690
5	258				

Specific Gravity of Potassium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$ = gms. of CH_3COOK in 100 gms. of solution.

$g\%$	$S_{17\cdot5°C.}^{17\cdot5°C.}$	$g\%$	$S_{17\cdot5°C.}^{17\cdot5°C.}$	$g\%$	$S_{17\cdot5°C.}^{17\cdot5°C.}$
1	1.0049	21	1.1058	41	1.2162
2	098	22	111	42	219
3	147	23	164	43	276
4	196	24	217	44	333
5	245	25	270	45	390
6	294	26	325	46	449
7	343	27	380	47	508
8	392	28	435	48	567
9	441	29	490	49	626
10	490	30	545	50	685
11	540	31	600	51	744
12	590	32	655	52	803
13	640	33	710	53	862
14	690	34	765	54	921
15	740	35	820	55	980
16	793	36	877	56	1.3041
17	846	37	934	57	102
18	899	38	991	58	163
19	952	39	1.2048	59	224
20	1.1005	40	105	60	285

Specific Gravity of Potassium Bisulphide Solutions.

(Bock, *Wied. Ann.*, 1887, **30**, 631.)

$g\%$ = gms. of KHS in 100 gms. of solution.

$g\%$	$S_{4°C.}^{18°C.}$	$g\%$	$S_{4°C.}^{18°C.}$
4.09	1.0232	33.43	1.2124
7.86	1.0456	39.22	1.2428
15.08	1.0889	51.22	1.3226

Specific Gravity of Potassium Bromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $KBrO_3$ in 100 gms. of solution.

$g\%$	$S_{\frac{19\cdot5°C.}{19\cdot5°C.}}$	$g\%$	$S_{\frac{19\cdot5°C.}{19\cdot5°C.}}$
1	1.009	6	1.046
2	16	7	54
3	24	8	62
4	31	9	70
5	39	10	79

Specific Gravity of Potassium Carbonate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 279.)

$g\%$ = gms. of K_2CO_3 in 100 gms. of solution.

$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$	$g\%$	$S_{\frac{15°C.}{15°C.}}$
1	1.00914	19	1.18265	36	1.37082
2	1829	20	9286	37	8279
3	2743	21	1.20344	38	9476
4	3658	22	1402	39	1.40673
5	4572	23	2459	40	1870
6	5513	24	3517	41	3104
7	6454	25	4575	42	4338
8	7396	26	5681	43	4573
9	8337	27	6787	44	6807
10	9278	28	7893	45	8041
11	1.10258	29	8999	46	9314
12	1238	30	1.30105	47	1.50588
13	2219	31	1261	48	1861
14	3199	32	2417	49	3135
15	4179	33	3573	50	4408
16	5200	34	4729	51	5728
17	6222	35	5885	52	7048
18	7243				

Density of Potassium Bromide Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 223 & 224.)

$g\%$ = gms. of KBr in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{4°C.}$	$g\%$	$S\frac{19\cdot5°C.}{4°C.}$	$g\%$	$S\frac{19\cdot5°C.}{4°C.}$
0.74	1.0036	5.62	1.0396	26.32	1.2200
1.47	1.0089	10.64	1.0790	32.27	1.2832
2.89	1.0192	19.24	1.1526	37.32	1.3403

Specific Gravity of Potassium Chlorate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $KClO_3$ in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$	$g\%$	$S\frac{19\cdot5°C.}{19\,5°C.}$
1	1.007	6	1.039
2	1.014	7	1.045
3	1.020	8	1.052
4	1.026	9	1.059
5	1.033	10	1.066

Density of Potassium Chloride Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 222 & 224.)

$g\%$ = gms. of KCl in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{4°C.}$	$g\%$	$S\frac{\cdot9\,5°C.}{4°C.}$
0.92	1.0043	12.98	1.0835
1.83	1.0100	18.29	1.1204
3.60	1.0213	22.98	1.1543
6.94	1.0432		

Specific Gravity of Potassium Chromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)

$g\% =$ gms. of K_2CrO_4 in 100 gms. of solution.

$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$	$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$	$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$	$g\%$	$S\frac{19 \cdot 5°C.}{19 \cdot 5°C.}$
1	1.0080	11	1.0925	21	1.1864	31	1.2921
2	161	12	1.1014	22	964	32	1.3035
3	243	13	104	23	1.2066	33	151
4	325	14	195	24	169	34	268
5	408	15	287	25	274	35	386
6	492	16	380	26	379	36	505
7	576	17	474	27	485	37	625
8	663	18	570	28	592	38	746
9	750	19	667	29	700	39	868
10	837	20	765	30	808	40	991

Specific Gravity of Potassium Chrome Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 497.)

$g\% =$ gms. of $K_2SO_4Cr_2(SO_4)_3 24H_2O$ in 100 gms. of solution.

Violet modification.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C}$
5	1.02725	15	1.08350
10	1.05500		

Green modification.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C}{15°C.}$
10	1.050	60	1.371
20	1.103	70	1.453
30	1.161	80	1.541
40	1.225	90	1.635
50	1.295		

Sp. Gr. of Potassium Dichromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)

$g\%$ = gms. of $K_2Cr_2O_7$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$	$g\%$	$\dfrac{S_{19\cdot5°C.}}{19\cdot5°C.}$
1	1.007	6	1.043	11	1.080
2	15	7	50	12	87
3	22	8	56	13	95
4	30	9	65	14	1.102
5	37	10	73	15	10

Sp. Gr. of Potassium Ferricyanide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $K_3Fe(CN)_6$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{13°C.}}{13°C.}$	$g\%$	$\dfrac{S_{13°C.}}{13°C.}$	$g\%$	$\dfrac{S_{13°C.}}{13°C.}$
1	1.0051	11	1.0595	21	1.1202
2	103	12	653	22	266
3	155	13	712	23	331
4	208	14	771	24	396
5	261	15	831	25	462
6	315	16	891	26	529
7	370	17	952	27	596
8	426	18	1.1014	28	664
9	482	19	076	29	732
10	538	20	139	30	802

Sp. Gr. of Potassium Ferrocyanide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $K_4Fe(CN)_6 3H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C}}{15°C.}$
1	1.0058	8	1.0479	15	1.0932
2	1.0116	9	1.0542	16	1.0999
3	1.0175	10	1.0605	17	1.1067
4	1.0234	11	1.0669	18	1.1136
5	1.0295	12	1.0734	19	1.1205
6	1.0356	13	1.0800	20	1.1275
7	1.0417	14	1.0866		

Density of Potassium Hydroxide Solutions.

(Pickering, 1893.)

$g\% =$ gms. of KOH in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$
1	1.0083	19	1.1786	36	1.3549
2	175	20	884	37	659
3	267	21	984	38	769
4	359	22	1.2083	39	879
5	452	23	184	40	991
6	544	24	285	41	1.4103
7	637	25	387	42	215
8	730	26	489	43	329
9	824	27	592	44	443
10	918	28	695	45	558
11	1.1013	29	800	46	673
12	108	30	905	47	790
13	203	31	1.3010	48	907
14	299	32	117	49	1.5025
15	396	33	224	50	143
16	493	34	331	51	262
17	590	35	440	52	382
18	688				

Specific Gravity of Potassium Iodate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\% =$ gms. of KIO_3 in 100 gms. of solution.

$g\%$	$S\frac{19·5°C.}{19·5°C.}$	$g\%$	$S\frac{19·5°C.}{19·5°C.}$
1	1.010	6	1.052
2	19	7	61
3	27	8	71
4	35	9	80
5	44	10	90

Density of Potassium Iodide Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 223/4.)

$g\%$ = gms. of KI in 100 gms. of solution.

$g\%$	$\dfrac{S_{19.5°C.}}{4°C.}$	$g\%$	$\dfrac{S_{19.5°C.}}{4°C.}$
1.03	1.0059	33.26	1.3097
2.03	1.0135	39.92	1.3959
3.99	1.0282	45.37	1.4766
7.67	1.0572	49.91	1.5458
14.24	1.1128	53.76	1.6115
24.94	1.2157	57.06	1.6722

Specific Gravity of Potassium Iron Alum Solutions.

(Gerlach, *Z. anal. Chem.*, 1889, **28**, 496.)

$g\%$ = gms. of $K_2SO_4Fe_2(SO_4)_3 24H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
5	1.0250	25	1.1340
10	1.0507	30	1.1645
15	1.0773	35	1.1967
20	1.1050		

Specific Gravity of Potassium Nitrate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of KNO_3 in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.00641	9	1.05861	17	1.11426
2	1283	10	6524	18	2150
3	1924	11	7215	19	2875
4	2566	12	7905	20	3599
5	3207	13	8596	21	4361
6	3870	14	9286		
7	4534	15	9977		
8	5197	16	1.10701		

Specific Gravity of Potassium Oxalate Solutions

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 315.)

$g\%$ = gms. of $K_2C_2O_4H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\ 5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$
1	1.0067	10	1.0656	19	1.1241
2	134	11	720	20	306
3	201	12	784	21	372
4	268	13	848	22	438
5	337	14	912	23	504
6	401	15	977	24	570
7	465	16	1.1043	25	638
8	529	17	109		
9	593	18	175		

Specific Gravity $S\frac{17\cdot5°C.}{17\cdot5°C.}$ of Solutions of the Acid Potassium Oxalates.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 315.)

$g\%$ = gms. of salt of formulæ given in 100 gms. of solution.

$g\%$	1	2	3	4	5
$KHC_2O_4 + H_2O$	1.0055	1.0110	1.0164	1.0218	1.0271
$KHC_2O_4, H_2C_2O_4 + H_2O$	1.0047	1.0093			

Specific Gravity of Potassium Sulphate Solutions

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of K_2SO_4 in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.00820	5	1.04105
2	1635	6	4947
3	2450	7	5790
4	3277	8	6644
		9	7499

Density of Potassium Sulphide Solutions.
(Bock, *Wied. Ann.*, 1887, **30**, 631.)
$g\% = $ gms. of K_2S in 100 gms. of solution.

$g\%$	$S\frac{18°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$
3.18	1.0265	15.06	1.1285	29.97	1.2672
4.98	1.0405	19.96	1.1738	38.08	1.3501
9.93	1.0829	24.64	1.2186	47.26	1.4596

Specific Gravity of Potassium Tartrate Solutions
(Gerlach, *Z. anal. Chem.*, 1887, **26**, 505.)
$g\% = $ gms. of $C_4H_4O_6K_2$ in 100 gms. of solution.

$g\%$	$S\frac{19·5°C.}{19·5°C.}$	$g\%$	$S\frac{19·5°C.}{19·5°C.}$
17.376	1.1198	52.071	1.4194
31.394	1.2299	60.333	1.5051
43.423	1.3355		

Specific Gravity of Rochelle Salt Solutions.
(Gerlach, *Z. anal. Chem.*, 1887, **26**, 505.)
$g\% = $ gms. of $C_4H_4O_6NaK4H_2O$ in 100 gms. of solution.
$G\% = $ gms. of $C_4H_4O_6NaK$ in 100 gms. of solution.

$g\%$	$G\%$	$S\frac{17·5°C.}{17·5°C.}$	$g\%$	$G\%$	$S\frac{17·5°C.}{17·5°C.}$
10	7.448	1.0510	40	29.729	1.2230
20	14.896	1.1050	50	37.240	1.2890
30	22.344	1.1620			

Density of Silver Nitrate Solutions.
(Landolt and Börnstein, from Kohlrausch, *Wied. Ann.*, 1879, **6**, 1–145.)
$g\% = $ gms. of $AgNO_3$ in 100 gms. of solution.

$g\%$	$S\frac{18°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$	$g\%$	$S\frac{18°C.}{4°C.}$
5	1.0422	20	1.1958	35	1.3945	50	1.6745
10	1.0893	25	1.2555	40	1.4773	55	1.7895
15	1.1404	30	1.3213	45	1.5705	60	1.9158

Specific Gravity of Sodium Acetate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 313.)

$g\%$ = gms. of CH_3COONa in 100 gms. of solution.

$g\%$	$\dfrac{S_{17.5°C.}}{17.5°C.}$	$g\%$	$\dfrac{S_{17.5°C.}}{17.5°C.}$	$g\%$	$\dfrac{S_{17.5°C.}}{17.5°C.}$
1	1.005	11	1.057	21	1.113
2	10	12	63	22	19
3	16	13	68	23	24
4	21	14	74	24	30
5	26	15	79	25	36
6	31	16	85	26	42
7	36	17	90	27	48
8	42	18	96	28	54
9	47	19	1.101	29	60
10	52	20	07	30	66
				31	72

Specific Gravity of Sodium Arsenate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 296.)

$g\%$ = gms. of $Na_3AsO_4 12H_2O$ in 100 gms. of solution.
$G\%$ = gms. of Na_3AsO_4 in 100 gms. of solution.

$g\%$	$G\%$	$\dfrac{S_{17°C}}{17°C}$	$g\%$	$G\%$	$\dfrac{S_{17°C}}{17°C}$
1	0.49	1.0053	12	5.89	1.0659
2	0.98	107	13	6.38	716
3	1.47	161	14	6.87	773
4	1.96	215	15	7.36	830
5	2.45	270	16	7.85	887
6	2.94	325	17	8.34	945
7	3.43	380	18	8.83	1.1003
8	3.92	435	19	9.32	061
9	4.41	491	20	9.81	120
10	4.91	547	21	10.30	179
11	5.40	603	22	10.79	238

Specific Gravity of Acid Sodium Arsenate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of $Na_2HAsO_4 12H_2O$ in 100 gms. of solution.
$G\%$ = gms. of Na_2HAsO_4 in 100 gms. of solution.

$g\%$	$G\%$	$S_{14°C.}^{14°C.}$	$g\%$	$G\%$	$S_{14°C.}^{14°C.}$
1	0.46	1.0042	21	9.71	1.0953
2	0.93	084	22	10.18	1.1002
3	1.39	126	23	10.64	052
4	1.85	168	24	11.10	102
5	2.31	212	25	11.57	153
6	2.78	256	26	12.03	204
7	3.24	300	27	12.49	255
8	3.70	344	28	12.95	306
9	4.16	389	29	13.42	358
10	4.63	434	30	13.88	410
11	5.09	479	31	14.34	463
12	5.55	525	32	14.80	516
13	6.01	571	33	15.27	569
14	6.48	618	34	15.73	623
15	6.94	665	35	16.19	677
16	7.40	712	36	16.65	731
17	7.86	759	37	17.12	786
18	8.33	807	38	17.58	818
19	8.78	855	39	18.04	896
20	9.25	904	40	18.50	952

Specific Gravity of Sodium Bromate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $NaBrO_3$ in 100 gms. of solution.

$g\%$	$S_{19·5°C.}^{19·5°C.}$	$g\%$	$S_{19·5°C.}^{19·5°C.}$
2	1.016	18	1.156
4	33	20	78
6	49	22	99
8	66	24	1.220
10	83	26	42
12	1.101	28	65
14	20	30	89
16	37		

Density of Sodium Bromide Solutions.

(Baxter and Wallace, *J. Am. Chem. Soc.*, 1916, **38**, 70.)
G=gms. of NaBr in 1 litre of solution.

G.	$S \frac{0°C.}{4°C.}$	G.	$S \frac{25°C.}{4°C.}$
563.89	1.42228	563.49	1.40972
281.17	1.21601	280.95	1.20608
112.67	1.08854	112.58	1.08200
56.03	1.04444	56.00	1.03962
27.88	1.02222	27.86	1.01833

Specific Gravity of Sodium Carbonate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 279.)
$g\%$ = gms. of Na_2CO_3 in 100 gms. of solution.

$g\%$	$S \frac{15°C.}{15°C.}$	$g\%$	$S \frac{15°C.}{15°C.}$	$g\%$	$S \frac{15°C.}{15°C.}$
1	1.01050	6	1.06309	11	1.11655
2	2101	7	7369	12	2740
3	3151	8	8430	13	3845
4	4201	9	9500	14	4950
5	5255	10	1.10571		

Change in Specific Gravity of Sodium Carbonate Solutions with Temperature.

(Lunge and Keane, " Tech. Methods of Chem. Anal., 1908,
Vol. I, p. 449.)
C=fall in specific gravity for 1°C. rise at room temperature.

$S \frac{15°C.}{15°C.}$	C.
1.01 to 1.05	0.0002
1.06 ,, 1.07	0.0003
1.08 ,, 1.11	0.0004
1.12 ,, 1.17	0.0004
1.18 ,, 1.20	0.0004
1.21 ,, 1.24	0.0005

Specific Gravity of Sodium Chlorate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)

$g\%$ = gms. of $NaClO_3$ in 100 gms. of solution.

$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$
1	1.007	15	1.108	29	1.225
2	15	16	16	30	35
3	21	17	24	31	44
4	28	18	31	32	52
5	35	19	40	33	62
6	41	20	47	34	72
7	48	21	55	35	82
8	55	22	65	36	91
9	63	23	74	37	1.301
10	70	24	81	38	11
11	78	25	90	39	21
12	85	26	1.200	40	31
13	94	27	08		
14	1.100	28	16		

Specific Gravity of Sodium Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)

$g\%$ = gms. of $NaCl$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.00725	10	1.07335	19	1.14315
2	1450	11	8097	20	5107
3	2174	12	8859	21	5931
4	2899	13	9622	22	6755
5	3624	14	1.10384	23	7580
6	4366	15	1146	24	8404
7	5108	16	1938	25	9228
8	5851	17	2730	26	1.20098
9	6593	18	3523		

Density of Sodium Hydroxide Solutions.

(Bousfield and Lowry, *Phil. Trans.*, 1905, A, **204**, 279.)
$g\%$ = gms. of NaOH in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C.}{4°C.}$	$g\%$	$S\frac{15°C}{4°C.}$
1	1.01065	18	1.19973	35	1.3830
2	2198	19	1.21079	36	933
3	3322	20	2183	37	1.4034
4	4441	21	3285	38	135
5	5554	22	439	39	235
6	6666	23	5485	40	334
7	7777	24	658	41	432
8	8887	25	768	42	529
9	9997	26	877	43	625
10	1.11107	27	986	44	720
11	2217	28	1.3094	45	815
12	3327	29	202	46	911
13	4436	30	309	47	1.5007
14	5545	31	415	48	102
15	6653	32	520	49	196
16	7761	33	624	50	290
17	8868	34	728		

δ = fall in density per °C. rise in temp. at room temperatures.

$g\%$	δ	$g\%$	δ
1 to 2	0.0002	11 to 23	0.0005
3 ,, 5	0.0003	24 ,, 35	0.0006
6 ,, 10	0.0004	36 ,, 50	0.0007

Specific Gravity of Sodium Iodate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 290.)
$g\%$ = gms. of NaIO$_3$ in 100 gms. of solution.

$g\%$	$S\frac{19.5°C.}{19.5°C.}$	$g\%$	$S\frac{19.5°C.}{19.5°C.}$
1	1.010	6	1.054
2	19	7	65
3	28	8	75
4	36	9	85
5	44	10	95

Density of Sodium Iodide Solutions.

(Baxter and Wallace, *J. Am. Chem. Soc.*, 1916, **38**, 70.)

G = gms. of NaI in 1 litre of solution.

G.	$S \frac{0°C.}{4°C.}$	G.	$S \frac{25°C}{4°C.}$
1040.38	1.78425	1039.65	1.76970
518.75	1.39837	518.38	1.38569
207.86	1.16237	207.71	1.15413
103.38	1.08136	103.31	1.07550
51.45	1.04067	51.41	1.03624

Density of Sodium Nitrate Solutions.

(J. Y. Buchanan, *Trans. Roy. Soc. Edin.*, 1912, **49**, 222 & 224.)

$g\%$ = gms. of $NaNO_3$ in 100 gms. of solution.

$g\%$	$S \frac{13·5°C.}{4°C.}$	$g\%$	$S \frac{19·5°C.}{4°C.}$
1.05	1.0055	25.37	1.1871
2.08	1.0125	29.82	1.2247
4.08	1.0261	33.77	1.2592
7.83	1.0525	37.30	1.2918
14.53	1.1012	40.48	1.3231
20.82	1.1459	43.34	1.3517

Specific Gravity of Di-Sodium Phosphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)

$g\%$ = gms. of $Na_2HPO_4 12H_2O$ in 100 gms. of solution.

$G\%$ = gms. of Na_2HPO_4 in 100 gms. of solution.

$g\%$	$G\%$	$S \frac{19°C.}{19°C.}$	$g\%$	$G\%$	$S \frac{9°C.}{19°C.}$
1	0.40	1.0041	7	2.78	1.0292
2	0.79	083	8	3.18	332
3	1.19	125	9	3.57	375
4	1.59	166	10	3.97	418
5	1.98	208	11	4.37	460
6	2.38	250	12	4.76	503

Specific Gravity of Tri-Sodium Phosphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 286.)
$g\%$ = gms. of $Na_3PO_412H_2O$ in 100 gms. of solution.
$G\%$ = gms. of Na_3PO_4 in 100 gms. of solution.

$g\%$	$G\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$G\%$	$\dfrac{S_{15°C.}}{15°C.}$
2	0.86	1.0086	14	6.05	1.0633
6	2.59	263	18	7.78	827
10	4.32	455	22	9.51	1.1025

Specific Gravity of Sodium Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 287.)
$g\%$ = gms. of $Na_2SO_410H_2O$ in 100 gms. of solution.
$G\%$ = gms. of Na_2SO_4 in 100 gms. of solution.

$g\%$	$G\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$G\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	0.44	1.004	16	7.06	1.064
2	0.88	08	17	7.50	69
3	1.32	13	18	7.94	73
4	1.76	16	19	8.38	77
5	2.21	20	20	8.82	82
6	2.65	24	21	9.26	86
7	3.09	28	22	9.70	90
8	3.53	32	23	10.14	94
9	3.97	36	24	10.58	98
10	4.41	40	25	11.02	1.103
11	4.85	44	26	11.47	07
12	5.29	47	27	11.91	11
13	5.73	52	28	12.35	16
14	6.17	56	29	12.79	20
15	6.61	60	30	13.23	25

Density of Sodium Sulphide Solutions.

(Bock, *Wied. Ann.*, 1867, **30**, 631.)
$g\%$ = gms. of Na_2S in 100 gms. of solution.

$g\%$	$\dfrac{S_{18°C.}}{4°C.}$	$g\%$	$\dfrac{S_{18°C.}}{4°C.}$
2.02	1.0212	14.02	1.1583
5.03	1.0557	16.12	1.1810
9.64	1.1102	18.15	1.2158

Specific Gravity of Sodium Sulphite Solutions.

(Cheneveau, *Ann. de chim. phys.*, 1907, (8), **12**, 145.)
$g\%$ = gms. of Na_2SO_3 in 100 gms. of solution.

$g\%$	$S\frac{19°C.}{19°C.}$	$g\%$	$S\frac{19°C.}{19°C.}$	$g\%$	$S\frac{19°C.}{19°C.}$
2	1.0180	8	1.0747	14	1.1348
4	.0365	10	.0944	16	.1553
6	.0554	12	.1145		

Specific Gravity of Sodium Thiosulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)
$g\%$ = gms. of $Na_2S_2O_3 5H_2O$ in 100 gms. of solution.
$G\%$ = gms. of $Na_2S_2O_3$ in 100 gms. of solution.

$g\%$	$G\%$	$S\frac{19°C.}{19°C.}$	$g\%$	$G\%$	$S\frac{19°C.}{19°C.}$
1	0.64	1.0052	26	16.56	1.1440
2	1.27	105	27	17.20	499
3	1.91	158	28	17.84	558
4	2.58	211	29	18.47	617
5	3.18	264	30	19.11	676
6	3.82	317	31	19.75	738
7	4.46	370	32	20.39	800
8	5.10	423	33	21.02	862
9	5.73	476	34	21.66	924
10	6.37	529	35	22.30	986
11	7.01	584	36	22.93	1.2048
12	7.64	639	37	23.57	110
13	8.28	695	38	24.21	172
14	8.92	751	39	24.85	234
15	9.56	807	40	25.48	297
16	10.19	863	41	26.12	362
17	10.83	919	42	26.76	427
18	11.47	975	43	27.39	492
19	12.10	1.1031	44	28.03	558
20	12.74	087	45	28.67	624
21	13.38	145	46	29.31	690
22	14.02	204	47	29.94	756
23	14.65	263	48	30.58	822
24	15.29	322	49	31.22	888
25	15.93	381	50	31.85	954

Density of Sodium Tartrate Solutions.

(Pribram and Glücksman, *Wien. Ber.*, 1898.)

$g\%$ = gms. of $Na_2C_4H_4O_6$ in 100 gms. of solution.

$g\%$	$S\frac{20°C.}{4°C.}$	$g\%$	$S\frac{20°C.}{4°C.}$
0.6059	1.00248	11.387	1.08056
2.4502	1555	15.237	1.10973
4.9563	3341	18.255	3381
6.7866	4671	22.608	6846
8.5866	5987	28.321	1.21559

Specific Gravity of Sodium Tungstate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 308.)

$g\%$ = gms. of $Na_2WO_4 2H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{24\cdot5°C.}{24\cdot5°C.}$	$g\%$	$S\frac{24\cdot5°C.}{24\cdot5°C.}$	$g\%$	$S\frac{24\cdot5°C.}{24\cdot5°C.}$
1	1.004	16	1.130	31	1.289
2	12	17	39	32	1.305
3	21	18	47	33	21
4	29	19	55	34	35
5	36	20	66	35	49
6	45	21	76	36	64
7	52	22	85	37	81
8	59	23	95	38	97
9	68	24	1.204	39	1.414
10	75	25	15	40	30
11	84	26	27	41	45
12	92	27	39	42	60
13	1.101	28	50	43	76
14	10	29	62	44	92
15	19	30	74		

Specific Gravity of Sugar Solutions.

(Plato, *Wiss. Abhand. Kaiserlich. Norm-Aich. Komm.,* vol. ii, 1900.)

$g\%$ = gms. of pure cane sugar in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
0	1.000000	34	1.149113	68	1.338439
1	3891	35	1.154074	69	1.344670
2	7809	36	9069	70	1.350940
3	1.011755	37	1.164099	71	7247
4	5728	38	9164	72	1.363593
5	9729	39	1.174267	73	9978
6	1.023758	40	9405	74	1.376399
7	7817	41	1.184581	75	1.382859
8	1.031903	42	9792	76	9358
9	6019	43	1.195040	77	1.395893
10	1.040163	44	1.200324	78	1.402466
11	4338	45	5646	79	9076
12	8543	46	1.211004	80	1.415724
13	1.052777	47	6400	81	1.422408
14	7043	48	1.221832	82	9130
15	1.061338	49	7302	83	1.435889
16	5664	50	1.232810	84	1.442685
17	1.070023	51	8355	85	9518
18	4412	52	1.243938	86	1.456386
19	8833	53	9558	87	1.463292
20	1.083285	54	1.255217	88	1.470233
21	7771	55	1.260913	89	7210
22	1.092288	56	6647	90	1.484223
23	6829	57	1.272420	91	1.491272
24	1.101422	58	8231	92	8356
25	6039	59	1.284079	93	1.505474
26	1.110689	60	9966	94	1.512627
27	5373	61	1.295891	95	9815
28	1.120089	62	1.301854	96	1.527037
29	4840	63	7856	97	1.534293
30	9625	64	1.313896	98	1.541582
31	1.134445	65	9974	99	8903
32	9300	66	1.326091	100	1.556259
33	1.144189	67	1.332246		

Change in Specific Gravity of Sugar Solutions with Temperature.

(Plato, *Ibid.*)

$g\%$ = gms. of pure cane sugar in 100 gms. of solution.
δ = fall in specific gravity relative to water at 15°C. for 1°C.
rise in temp. at room temperatures.

$g\%$	δ	$g\%$	δ	$g\%$	δ
0	0.00015	24	0.00028	48	0.00042
1	16	25	29	49	42
2	16	26	29	50	43
3	17	27	30	51	43
4	17	28	31	52	44
5	18	29	31	53	44
6	18	30	32	54	45
7	19	31	32	55	45
8	19	32	33	56	46
9	20	33	34	57	46
10	20	34	34	58	46
11	21	35	35	59	47
12	21	36	35	60	47
13	22	37	36	61	48
14	22	38	36	62	48
15	23	39	37	63	49
16	24	40	37	64	49
17	24	41	38	65	49
18	25	42	38	66	50
19	25	43	39	67	50
20	26	44	39	68	51
21	27	45	40	69	51
22	27	46	41	70	51
23	28	47	41		

Density and Specific Gravity of Sulphuric Acid Solutions.

(J. Domke, *Wiss. Abh. der K. Normal-Eichungs-Kommission,* 1904, Vol. V.)

$g\%$ = gms. of pure H_2SO_4 in 100 gms. of solution.

$g\%$	$S_{15°C.}$ $4°C.$	$S_{15°C.}$ $15°C.$	$g\%$	$S_{15°C.}$ $4°C.$	$S_{15°C.}$ $15°C.$
0	0.99913	1.00000	38	1.28915	1.29027
1	1.00611	0698	39	9781	9894
2	1293	1381	40	1.30654	1.30767
3	1967	2055	41	1534	1648
4	2639	2728	42	2422	2537
5	3316	3406	43	3319	3435
6	4002	4092	44	4226	4342
7	4695	4786	45	5144	5261
8	5395	5486	46	6073	6191
9	6100	6192	47	7013	7132
10	6810	6903	48	7964	8084
11	7526	7619	49	8926	9047
12	8248	8342	50	9900	1.40021
13	8976	9071	51	1.40885	1007
14	9710	9805	52	1882	2005
15	1.10450	1.10546	53	2890	3014
16	1196	1292	54	3909	4034
17	1948	2045	55	4939	5065
18	2705	2803	56	5980	6107
19	3468	3566	57	7031	7159
20	4236	4335	58	8092	8221
21	5009	5109	59	9163	9292
22	5788	5888	60	1.50244	1.50374
23	6572	6673	61	1334	1465
24	7362	7464	62	2432	2564
25	8157	8260	63	3539	3672
26	8957	9060	64	4654	4788
27	9761	9865	65	5777	5912
28	1.20570	1.20675	66	6908	7044
29	1384	1489	67	8047	8184
30	2202	2308	68	9194	9332
31	3024	3131	69	1.60349	1.60488
32	3850	3957	70	1511	1651
33	4681	4789	71	2680	2821
34	5517	5626	72	3855	3997
35	6358	6468	73	5035	5176
36	7204	7314	74	6218	6362
37	8056	8167	75	7402	7547

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$g\%$	$S_{15°C.}/4°C.$	$S_{15°C.}/15°C.$	$g\%$	$S_{15°C.}/4°C.$	$S_{15°C.}/15°C.$
76	1.68585	1.68731	89	1.81407	1.81564
77	9764	9911	90	1977	2135
78	1.70935	1.71083	91	2484	2642
79	2094	2243	92	2929	3088
80	3236	3386	93	3312	3471
81	4355	4506	94	3631	3790
82	5443	5595	95	3880	4040
83	6489	6642	96	4057	4217
84	7482	7636	97	4145	4305
85	8412	8567	98	4115	4275
86	9272	9428	99	3933	4093
87	1.80058	1.80214	100	3570	1.83729
88	0769	0926			

Density and Specific Gravity of Concentrated Sulphuric Acid Solutions. (Domke, *loc. cit.*)

$g\%$ = gms. of H_2SO_4 in 100 gms. of solution.

$g\%$	$S_{15°C.}/4°C.$	$S_{15°C.}/15°C.$	$g\%$	$S_{15°C.}/4°C.$	$S_{15°C.}/15°C.$
90.0	1.81977	1.82135	95.0	1.83880	1.84040
.2	2083	2241	.2	3921	4082
.4	2187	2345	.4	3960	4120
.6	2289	2447	.6	3996	4156
.8	2388	2546	.8	4029	4189
91.0	2484	2642	96.0	4057	4217
.2	2578	2736	.2	4081	4241
.4	2669	2827	.4	4102	4262
.6	2758	2916	.6	4121	4281
.8	2845	3003	.8	4136	4296
92.0	2929	3088	97.0	4145	4305
.2	3011	3170	.2	4148	4309
.4	3090	3249	.4	4148	4308
.6	3166	3325	.6	4143	4303
.8	3240	3399	.8	4132	4292
93.0	3312	3471	98.0	4115	4275
.2	3381	3540	.2	4092	4252
.4	3448	3607	.4	4063	4223
.6	3512	3671	.6	4026	4186
.8	3573	3732	.8	3983	4143
94.0	3631	3790	99.0	3933	4093
.2	3687	3846	.2	3879	4039
.4	3740	3899	.4	3815	3975
.6	3790	3949	.6	3742	3902
.8	3837	3997	.8	3660	3819
95.0	3880	4040	100.0	3570	3775

Hydrometer Correction Table for Sulphuric Acid.

(Domke, *loc. cit.*)

$g\%$ = gms. of H_2SO_4 in 100 gms. of solution (*approximately*).
S = reading on hydrometer at $t°$C. The hydrometer is supposed to read $\frac{S_{15°C.}}{4°C.}$ correctly in sulphuric acid solutions at 15°C.

The true density $\frac{S_{15°C.}}{4°C.}$ of the acid is given by

$$\frac{S_{15°C.}}{4°C.} = S + C(t - 15).$$

The true strength of the acid may be obtained from the true density by reference to the preceding tables.

$g\%$	S.	C.	$g\%$	S.	C.
0	0.999	0.00013	27	1.198	0.00065
1	1.006	16	28	1.206	66
2	1.013	18	29	1.214	67
3	1.020	21	30	1.222	68
4	1.026	23	31	1.230	68
5	1.033	25	32	1.239	69
6	1.040	27	33	1.247	69
7	1.047	30	34	1.255	70
8	1.054	32	35	1.264	70
9	1.061	34	36	1.272	71
10	1.068	36	37	1.281	71
11	1.075	39	38	1.289	72
12	1.082	41	39	1.298	72
13	1.090	43	40	1.307	73
14	1.097	45	41	1.315	73
15	1.105	47	42	1.324	73
16	1.112	49	43	1.333	74
17	1.119	51	44	1.342	74
18	1.127	52	45	1.351	74
19	1.135	54	46	1.361	75
20	1.142	56	47	1.370	75
21	1.150	57	48	1.380	76
22	1.158	59	49	1.389	76
23	1.166	60	50	1.399	77
24	1.174	61	51	1.409	77
25	1.182	63	52	1.419	78
26	1.190	64	53	1.429	78

$v\%$	S.	C.		$v\%$	S.	C.
54	1.439	0.00079		78	1.709	0.00098
55	1.449	79		79	1.721	99
56	1.460	80		80	1.732	0.00102
57	1.470	81		81	1.744	104
58	1.481	82		82	1.754	106
59	1.492	82		83	1.765	107
60	1.502	83		84	1.775	108
61	1.513	84		85	1.784	108
62	1.524	84		86	1.793	108
63	1.535	85		87	1.801	107
64	1.547	86		88	1.808	107
65	1.558	87		89	1.814	106
66	1.569	87		90	1.820	105
67	1.580	88		91	1.825	104
68	1.592	89		92	1.829	103
69	1.603	89		93	1.833	102
70	1.615	90		94	1.836	101
71	1.627	91		95	1.839	100
72	1.639	92		96	1.841	0.00099
73	1.650	93		97	1.841	99
74	1.662	94		98	1.841	0.00100
75	1.674	95		99	1.839	101
76	1.686	96		100	1.836	102
77	1.698	97				

Dilution Table for Sulphuric Acid.

(Domke, *loc. cit.*)

$S\frac{15}{4}$ = required density of solution.

$g\%$ = gms. of sulphuric acid in 100 gms. of solution of required density (to nearest 0·5%).

v = vol. in c.c. of acid of $S\frac{15}{4}$ = 1·84 (*i.e.*, 95% acid) at 15°C. to be added to 1000 c.c. of water at 15°C.

V = vol. of resulting solution in c.c. at 15°C.

dv = contraction due to admixture in c.c.

$S\frac{15°C.}{4°C.}$	$g\%$	v	V	dv
1.01	1.5	9	1006	3
.02	3.0	18	1012	6
.03	4.5	27	1018	9
.04	6.0	36	1025	11
1.05	7.5	46	1032	14
.06	9.0	55	1039	16
.07	10.5	65	1046	19
.08	11.5	75	1053	22
.09	13.0	86	1061	25
1.10	14.5	96	1069	27
.11	16.0	107	1077	30
.12	17.0	118	1086	32
.13	18.5	129	1095	34
.14	19.5	141	1104	37
1.15	21.0	153	1113	40
.16	22.5	165	1123	42
.17	23.5	177	1133	44
.18	25.0	190	1143	47
.19	26.0	203	1154	49
1.20	27.5	217	1165	52
.21	28.5	231	1177	54
.22	30.0	245	1189	56
.23	31.0	260	1201	59
.24	32.0	275	1214	61
1.25	33.5	291	1228	63
.26	34.5	307	1242	65
.27	36.0	324	1257	67
.28	37.0	342	1272	70
.29	38.0	360	1287	73

$S\frac{15°C.}{4°C.}$	$g\%$	v	V	dv
1.30	39.0	378	1303	75
.31	40.5	397	1320	77
.32	41.5	417	1338	79
.33	42.5	437	1356	81
.34	44.0	458	1375	83
1.35	45.0	480	1394	86
.36	46.0	502	1414	88
.37	47.0	525	1434	91
.38	48.0	548	1455	93
.39	49.0	572	1477	95
1.40	50.0	598	1500	98
.41	51.0	624	1523	101
.42	52.0	651	1547	104
.43	53.0	678	1572	106
.44	54.0	707	1598	109
1.45	55.0	737	1624	113
.46	56.0	768	1652	116
.47	57.0	800	1681	119
.48	58.0	834	1712	122
.49	59.0	869	1744	125
1.50	60.0	905	1777	128
.51	60.5	943	1811	132
.52	61.5	983	1848	135
.53	62.5	1025	1886	139
.54	63.5	1069	1926	143
1.55	64.5	1115	1969	146
.56	65.0	1163	2014	149
.57	66.0	1214	2059	155
.58	67.0	1266	2110	158
.59	68.0	1325	2162	163
1.60	68.5	1386	2217	169
.61	69.5	1450	2277	173
.62	70.5	1517	2340	177
.63	71.5	1589	2407	182
.64	72.0	1666	2479	187
1.65	73.0	1749	2556	193
.66	74.0	1839	2640	199
.67	74.5	1934	2729	205
.68	75.5	2038	2827	211
.69	76.5	2151	2934	217
1.70	77.0	2276	3051	225

$\dfrac{S 15°C.}{4°C.}$	$g\%$	$v.$	V	$dv.$
.71	78.0	2414	3182	232
.72	79.0	2566	3326	240
.73	80.0	2737	3488	249
.74	80.5	2932	3675	257
1.75	81.5	3158	3892	266
.76	82.5	3424	4147	277
.77	83.5	3745	4457	288
.78	84.5	4147	4848	299
.79	85.5	4675	5364	311
1.80	87.0	5425	6101	324
.81	88.5	6599	7260	339
.82	90.0	8762	9407	355
.83	92.0	14507	15132	375

Specific Gravity of Fuming Sulphuric Acid.

(Marshall, " Explosives," Vol. I, p. 103, 1917.)

$g\%$ = gms. of free SO_3 in 100 gms. of acid.
G = total gms. of SO_3 in 100 gms. of acid.

$g\%$	$G\%$	$\dfrac{S 15°C.}{15°C.}$
10	83.46	1.888
20	85.30	1.920
30	87.14	1.957
40	88.97	1.979
50	90.81	2.009
60	92.65	2.020
70	94.48	2.018
80	96.32	2.008
90	98.16	1.990
100	100.00	1.984

Note.—Oleum with 0% to 30% free SO_3 is liquid at 15°C.
30% ,, 56% ,, ,, solid ,,
56% ,, 73% ,, ,, liquid ,,
73% ,, 100% ,, ,, solid ,,

Specific Gravity of Tannic Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 319.)

$g\%$ = gms. of $C_{14}H_{10}O_9$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$
1	1.0040	8	1.0324	15	1.0614
2	080	9	365	16	656
3	120	10	406	17	698
4	160	11	447	18	740
5	201	12	489	19	782
6	242	13	530	20	824
7	283	14	572		

Specific Gravity of Tartar Emetic Solutions

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 315.)

$g\%$ = gms. of $C_4H_4O_6K(SbO) + \frac{1}{2}H_2O$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$	$g\%$	$\dfrac{S_{17\cdot5°C.}}{17\cdot5°C.}$
0.5	1.005	3.5	1.022
1.0	1.007	4.0	1.027
1.5	1.009	4.5	1.031
2.0	1.012	5.0	1.035
2.5	1.015	5.5	1.038
3.0	1.018	6.0	1.041

Specific Gravity of Ordinary (d) Tartaric Acid Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 295.)

$g\%$ = gms. of $C_4H_6O_6$ in 100 gms. of solution.

$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$	$g\%$	$\dfrac{S_{15°C.}}{15°C.}$
1	1.0045	20	1.0969	40	1.2078
2	090	22	1.1072	°	198
4	179	24	175	44	317
6	273	26	282	46	441
8	371	28	393	48	568
10	469	30	505	50	696
12	565	32	615	52	828
14	661	34	725	54	961
16	761	36	840	56	1.3093
18	865	38	959		

Specific Gravity of Tin (Stannic) Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 281.)
$g\% =$ gms. of $SnCl_4 5H_2O$ in 100 gms. of solution.

$g\%$	$S_{g\%} \frac{15°C.}{15°C.}$	$g\%$	$S \frac{15°C.}{15°C.}$	$g\%$	$S \frac{15°C.}{15°C.}$	$g\%$	$S \frac{15°C.}{15°C.}$
1	1.006	25	1.158	49	1.357	73	1.627
2	1.012	26	1.165	50	1.365	74	1.641
3	1.018	27	1.173	51	1.376	75	1.654
4	1.024	28	1.180	52	1.386	76	1.669
5	1.030	29	1.187	53	1.396	77	1.683
6	1.036	30	1.195	54	1.406	78	1.698
7	1.042	31	1.202	55	1.415	79	1.712
8	1.048	32	1.210	56	1.426	80	1.727
9	1.053	33	1,218	57	1.437	81	1.743
10	1.060	34	1.226	58	1.447	82	1.759
11	1.066	35	1.234	59	1.458	83	1.775
12	1.072	36	1.242	60	1.468	84	1.791
13	1.078	37	1.250	61	1.480	85	1.807
14	1.084	38	1,25?	2	1.491	85	1.824
15	1.090	39	1.267	63	1.503	87	1.842
16	1.097	40	1.276	64	1.514	88	1.859
17	1.104	41	1.284	65	1.525	89	1.876
18	1.110	42	1.293	66	1.538	90	1.894
19	1.117	43	1.302	67	1.550	91	1.913
20	1.124	44	1.310	68	1.563	92	1.932
21	1.130	45	1.319	69	1.575	93	1.950
22	1.137	46	1.329	70	1.587	94	1.969
23	1.144	47	1.338	71	1.601	95	1.988
24	1.151	48	1.347	72	1.614		

Specific Gravity of Zinc Bromide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)
$g\% =$ gms. of $ZnBr_2$ in 100 gms. of solution.

$g\%$	$S \frac{19·5°C.}{19·5°C.}$	$g\%$	$S \frac{19·5°C.}{19·5°C.}$
5	1.045	35	1.400
10	1.093	40	1.475
15	1.196	45	1.560
20	1.204	50	1.650
25	1.265	55	1.755
30	1.330	60	1.875

Specific Gravity of Zinc Chloride Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 283.)

$g\%$ = gms. of $ZnCl_2$ in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$	$g\%$	$S\frac{19\ 5°C.}{19\cdot5°C.}$	$g\%$	$S\frac{19\ 5°C.}{19\ 5°C.}$	$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$
1	1.010	16	1.146	31	1.304	46	1.500
2	1.020	17	1.155	32	1.316	47	1.518
3	1.029	18	1.165	33	1.329	48	1.533
4	1.037	19	1.175	34	1.340	49	1.550
5	1.045	20	1.186	35	1.352	50	1.566
6	1.053	21	1.196	36	1.366	51	1.581
7	1.063	22	1.207	37	1.380	52	1.600
8	1.072	23	1.218	38	1.392	53	1.615
9	1.082	24	1.228	39	1.406	54	1.631
10	1.091	25	1.238	40	1.420	55	1.650
11	1.100	26	1.249	41	1.432	56	1.669
12	1.110	27	1.260	42	1.446	57	1.686
13	1.120	28	1.270	43	1.460	58	1.704
14	1.128	29	1,281	44	1.473	59	1.724
15	1.137	30	1.291	45	1.488	60	1.740

Specific Gravity of Zinc Iodide Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 285.)

$g\%$ = gms. of ZnI_2 in 100 gms. of solution.

$g\%$	$S\frac{19\cdot5°C.}{19\ 5°C.}$	$g\%$	$S\frac{19\cdot5°C.}{19\cdot5°C.}$
5	1.045	45	1.560
10	1.091	50	1.650
15	1.140	55	1.754
20	1.196	60	1.875
25	1.255	65	2.020
30	1.368	70	2.180
35	1.390	75	2.360
40	1.420		

Specific Gravity of Zinc Nitrate Solutions.

(Gerlach, *Z. anal. Chem.*, 1888, **27**, 310.)

$g\%$ = gms. of $Zn(NO_3)_2$ in 100 gms. of solution.

$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$	$g\%$	$S\frac{17\cdot5°C.}{17\cdot5°C.}$
1	1.0099	14	1.1376	27	1.2892	40	1.4572
2	198	15	476	28	1.3018	41	707
3	297	16	586	29	144	42	844
4	396	17	696	30	268	43	981
5	496	18	806	31	395	44	1.5118
6	590	19	916	32	524	45	258
7	684	20	1.2024	33	652	46	403
8	778	21	147	34	780	47	648
9	872	22	270	35	906	48	693
10	968	23	393	36	1.4039	49	838
11	1.1070	24	516	37	172	50	984
12	172	25	640	38	305		
13	274	26	766	39	438		

Specific Gravity of Zinc Sulphate Solutions.

(Gerlach, *Z. anal. Chem.*, 1869, **8**, 288.)

$g\%$ = gms. of $ZnSO_4,7H_2O$ in 100 gms. of solution.

$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$	$g\%$	$S\frac{15°C.}{15°C.}$
1	1.006	21	1.130	41	1.280
2	13	22	37	42	88
3	19	23	43	43	95
4	24	24	50	44	1.304
5	29	25	57	45	10
6	35	26	64	46	20
7	41	27	71	47	30
8	47	28	79	48	37
9	53	29	85	49	46
10	59	30	93	50	53
11	66	31	1.200	51	62
12	73	32	09	52	70
13	79	33	16	53	80
14	85	34	24	54	90
15	90	35	31	55	99
16	97	36	40	56	1.406
17	1.103	37	46	57	16
18	10	38	55	58	25
19	16	39	63	59	35
20	24	40	71	60	45

Universal Dilution Table.

If 100 volumes of solution of the percentage strength by volume shewn in the first column are diluted until the total volume has one of the values given in the body of the table the strength of the diluted solution is that given at the head of the column above the volume of the diluted solution. For example, suppose that it is required to dilute a solution whose strength is 75% by volume to a strength of 20% by volume. From the table it will be seen that each 100 cc. of the original solution must be diluted until the total volume of the solution is 375 cc.

If it is desired to make 1000 cc. of the 20% solution from the 75% solution then $100 \times \frac{1000}{375}$ i.e., 266.67 cc. of the latter must be diluted to 1000 cc. The initial and final temperatures must be the same.

PERCENTAGE BY VOLUME AFTER DILUTION.

Original Percentage by volume.	95.	90.	85.	80.	75.	70.	65.	60.	55.	50.	45.	40.	35.	30.	25.	20.	15.	10.	5.
100	105.26	111.11	117.66	125.00	133.33	142.86	153.85	166.67	181.82	200.00	222.22	250.00	285.71	333.33	400.00	500.00	666.67	1000.00	2000.00
95	—	105.56	111.76	118.75	126.67	135.71	146.15	158.33	172.73	190.00	211.11	237.50	271.43	316.67	380.00	475.00	633.33	950.00	1900.00
90	—	—	105.88	112.50	120.00	128.57	138.46	150.00	163.64	180.00	200.00	225.00	257.14	300.00	360.00	450.00	600.00	900.00	1800.00
85	—	—	—	106.25	113.33	121.43	130.77	141.67	154.54	170.00	188.89	212.50	242.86	283.33	340.00	425.00	566.67	850.00	1700.00
80	—	—	—	—	106.67	114.29	123.08	133.33	145.45	160.00	177.78	200.00	228.57	266.67	320.00	400.00	533.33	800.00	1600.00
75	—	—	—	—	—	107.14	115.38	125.00	136.36	150.00	166.67	187.50	221.43	250.00	300.00	375.00	500.00	750.00	1500.00
70	—	—	—	—	—	—	107.69	116.67	127.27	140.00	155.56	175.00	200.00	233.33	280.00	350.00	466.67	700.00	1400.00
65	—	—	—	—	—	—	—	108.33	118.18	130.00	144.44	162.50	185.71	216.67	260.00	325.00	433.33	650.00	1300.00
60	—	—	—	—	—	—	—	—	109.09	120.00	133.33	150.00	171.43	200.00	240.00	300.00	400.00	600.00	1200.00
55	—	—	—	—	—	—	—	—	—	110.00	122.22	137.50	157.14	183.33	220.00	275.00	366.67	550.00	1100.00
50	—	—	—	—	—	—	—	—	—	—	111.11	125.00	142.86	166.67	200.00	250.00	333.33	500.00	1000.00
45	—	—	—	—	—	—	—	—	—	—	—	112.50	128.57	150.00	180.00	225.00	300.00	450.00	900.00
40	—	—	—	—	—	—	—	—	—	—	—	—	114.29	133.33	160.00	200.00	266.67	400.00	800.00
35	—	—	—	—	—	—	—	—	—	—	—	—	—	116.67	140.00	175.00	233.33	350.00	700.00
30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	120.00	150.00	200.00	300.00	600.00
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	125.00	166.67	250.00	500.00
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	133.33	200.00	400.00
15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	150.00	300.00
10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	200.00

Densities of Gases.

In gms. per litre (1000.027 cc.) at 0°C. under a pressure of 760 mm. of mercury at 0°C. and lat. 45° at sea-level. Where references to observers are not given the figures are not recent and not, presumably, of the same accuracy; where two observers are mentioned, the value given is the mean.

Gas.	Mol. wt. O=16	Rel. to O=16.	Gms / litre.	Observer.
Acetylene C_2H_2	26·02	13 094	1·1695	Maass /18
Air	—	14 475	1·2928	Leduc /17
Ammonia NH_3	17·03	8 630	0·7708	Perman /06
Argon A	39·88	1·9964	1·7831	Leduc /18 Schultze /15
Arsine AsH_3	77·98	39·0	3·48	
Boron chloride BCl_3	117·4	57·0	5·08	
,, fluoride BF_3	68·0	33·4	2 99	
Butane C_4H_{10}	58·10	29·11	2·601	
Carbon dioxide CO_2	44.00	22 133	1 9768	Guye /05
,, monoxide CO	28·00	14·000	1·2504	Rayleigh /98
,, oxychloride $COCl_2$ at 100°C.	98.92	50 7	4·53	
,, oxysulphide COS	60·06	30·4	2·72	
Chlorine Cl_2	70 92	35·98	3 214	Jacquerod /13
,, monoxide Cl_2O	86·92	43·54	3 889	
,, dioxide ClO_2	67·46	33·8	3·02	
Cyanogen C_2N_2	52·02	26·16	2 337	
Ethane C_2H_6	30 06	15·187	1·3565	Stahrfoss /18
Ethylamine C_2H_7N at 100°C..	45.08	22 75	2·032	
Ethyl chloride C_2H_5Cl at 100°C.	64·51	32·11	2·868	
Ethylene C_2H_4	28·04	14·111	1·2603	Bateucas /18
Fluorine F_2	38·0	19·0	1·69	

Gas.	Mol. wt. O=16	Density observed. Rel. to O=16.	Gms./ litre.	Observer.
Helium He	4·00	1·9984	0·17849	Taylor /17
Hydrogen H_2	2·016	1·0062	0·08987	Morley
,, bromide HBr	80·93	40·802	3·6442	{ Moles /16 Murray /17
,, chloride HCl	36·47	18·360	1·6398	Guye
,, fluoride HF at 100°C.	20·0	10·32	0·922	
,, iodide HI	127·93	64·2	5·74	
,, selenide H_2Se	81·2	41·107	3·6715	Bruylants /12
,, sulphide H_2S	34·08	17·23	1·539	
,, telluride H_2Te......	129·5	65·0	5·80	
Krypton Kr	82·92	41·52	3·708	Moore /08
Methane CH_4..................	16·04	8·025	0·7168	Baume /09
Methylamine CH_5N	31·05	15·62	1·395	
Methyl chloride CH_3Cl	50·49	25·04	2·236	
,, ether C_2H_6O	46·06	23·63	2·1103	Maass /18
,, fluoride CH_3F	34·0	17·30	1·5451	Moles /21
Neon Ne	20·2	10·07	0·8986	Leduc /14
Nitric oxide NO	30·01	15·005	1·3402	Gray, Guye
Nitrogen N_2	28·02	14·004	1·2507	Gray, Moles /22
Nitrosyl chloride NOCl	65·47	33·42	2·985	
Nitrogen peroxide N_2O_4 at 26·7°	92·02	38·3	3·42	
,, ,, ,, 60·2°		39·1		
,, ,, ,, 100·1°		24·3		
,, ,, NO_2 at 140°	46·01	23·0	2·05	
Nitrous oxide N_2O	44·02	22·143	1·9777	Guye
Oxygen O_2	32·00	16·000	1·42906	Germann /14
Phosphine PH_3	34·06	17·57	1·569	
Phosphorus chlorofluoride PCl_2F_3	158·9	78·2	6·98	
,, oxyfluoride POF_3..	104·0	53·25	4·75	
,, pentafluoride PF_5	126·0	65·0	5·80	
,, trifluoride PF_3 ..	88·0	43·7	3·91	
Propylene C_3H_6	39·04	21·67	1·936	
Silicon fluoride SiF_4	104·3	52·42	4·684	Germann /17
Sulphur dioxide SO_2	64·06	32·767	2·9266	{ Berthelot Jacquerod
Xenon X	130·2	65·51	5·851	Moore /08

Density of Air half saturated with Water Vapour.

In mgms. per cc.   (Donaldson, 1911, unpublished).

°C.	Pressure in mm. of mercury.							
	740	745	750	755	760	765	770	775
9	1.216	1.224	1.233	1.241	1.249	1.257	1.265	1.274
11	1.207	1.215	1.223	1.232	1.240	1.248	1.256	1.264
13	1.198	1.206	1.214	1.223	1.231	1.239	1.247	1.255
15	1.189	1.197	1.206	1.214	1.222	1.230	1.238	1.246
17	1.181	1.189	1.197	1.205	1.213	1.221	1.229	1.237
19	1.172	1.180	1.188	1.196	1.204	1.212	1.220	1.228
21	1.163	1.171	1.179	1.187	1.195	1.203	1.211	1.219
23	1.155	1.163	1.170	1.178	1.186	1.194	1.202	1.210
25	1.146	1.154	1.162	1.170	1.177	1.185	1.193	1.201
27	1.138	1.145	1.153	1.161	1.169	1.176	1.184	1.192

Tables for Use in Gas-Volumetric Analysis.

In the following pages are given tables which have been deduced for various analytical operations; it should be noticed that these do not give the actual density of the moist gas, but the weight of the gas alone contained therein, that of the water having been subtracted. The error due to inaccuracy of the reduction to N.T.P. and to use of incorrect values of density may amount to 0.3% in the worst cases for the CO_2 table; the others are accurate to about 0.1%. The hydrogen table is useful not only in the determination of equivalents of metals, etc., but also in calculating vapour densities from the volume of air displaced in Victor Meyer's method.

When greater accuracy is required the Tables for Correction to N.T.P. should be used in connection with the values of normal density given above.

Carbon Dioxide.

Weight, in mgms., of Carbon Dioxide in 1 cc. of the Gas saturated with Aqueous Vapour. (Regnault).

t°C.	740	744	748	750	752	754	756	758	760	762	764	766	768	770
10	1.824	1.834	1.844	1.849	1.854	1.859	1.864	1.869	1.874	1.879	1.884	1.889	1.894	1.899
11	16	26	36	41	46	51	55	61	66	71	76	81	86	91
12	08	18	28	38	38	43	48	53	58	63	68	73	78	83
13	00	10	20	25	30	35	40	45	50	55	60	65	70	75
14	1.792	02	12	17	22	27	32	37	42	47	52	56	61	66
15	84	1.794	04	09	14	18	23	28	33	38	43	48	53	58
16	76	86	1.796	00	05	10	15	20	25	30	35	39	44	49
17	68	77	87	1.792	1.797	02	06	11	16	21	26	31	36	41
18	59	69	79	84	88	1.793	1.798	03	08	13	18	22	27	32
19	51	60	70	75	80	85	89	1.794	1.799	04	09	14	19	23
20	42	52	61	66	71	76	81	86	91	1.795	00	05	10	15
21	34	43	53	58	63	67	72	77	82	87	1.791	1.796	01	06
22	25	35	44	49	54	59	63	68	73	78	83	87	1.792	1.797
23	16	26	35	40	45	50	55	59	64	69	74	78	83	88
24	08	17	27	31	36	41	45	50	55	60	65	69	74	79
25	1.699	08	18	22	27	32	36	41	46	51	55	60	65	70

Weight in mg. of Dry HYDROGEN in one litre of the Gas saturated with Aqueous Vapour at the given temperature and pressure. (Weight of one litre of Hydrogen at N.T.P. taken as ·08995 gm.)
Vanino, 1913.

mm.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°
720	81.15	80.79	80.44	80.09	79.73	79.35	78.98	78.61	78.23	77.86	77.50	77.10	76.70	76.30	75.91	75.50
722	81.38	81.02	80.67	80.32	79.96	79.57	79.20	78.83	78.45	78.08	77.72	77.32	76.92	76.52	76.13	75.72
724	81.61	81.25	80.89	80.54	80.18	79.80	79.42	79.05	78.67	78.30	77.94	77.54	77.14	76.74	76.34	75.93
726	81.84	81.48	81.12	80.77	80.41	80.02	79.65	79.28	78.89	78.52	78.16	77.76	77.35	76.96	76.56	76.15
728	82.07	81.70	81.34	80.99	80.63	80.25	79.87	79.50	79.11	78.74	78.38	77.98	77.57	77.18	76.78	76.37
730	82.29	81.93	81.57	81.22	80.86	80.47	80.10	79.72	79.34	78.96	78.60	78.20	77.79	77.40	77.00	76.58
732	82.52	82.16	81.80	81.45	81.08	80.70	80.32	79.94	79.56	79.18	78.80	78.42	78.01	77.61	77.22	76.80
734	82.75	82.39	82.03	81.67	81.31	80.92	80.54	80.17	79.78	79.40	79.04	78.63	78.23	77.83	77.43	77.02
736	82.98	82.61	82.25	81.90	81.53	81.14	80.77	80.39	80.00	79.62	79.26	78.85	78.45	78.05	77.65	77.23
738	83.21	82.84	82.48	82.12	81.76	81.37	80.99	80.61	80.22	79.84	79.50	79.07	78.67	78.27	77.87	77.45
740	83.44	83.07	82.71	82.35	81.98	81.59	81.21	80.83	80.44	80.07	79.71	79.29	78.89	78.49	78.08	77.67
742	83.65	83.30	82.93	82.58	82.21	81.82	81.44	81.06	80.67	80.29	79.93	79.51	79.11	78.71	78.30	77.88
744	83.89	83.52	83.16	82.80	82.43	82.04	81.66	81.28	80.89	80.51	80.15	79.73	79.33	78.92	78.52	78.10
746	84.12	83.75	83.39	83.03	82.66	82.27	81.88	81.50	81.11	80.73	80.37	79.95	79.55	79.14	78.74	78.32
748	84.35	83.98	83.61	83.25	82.89	82.49	82.11	81.73	81.34	80.95	80.59	80.17	79.76	79.36	78.96	78.53
750	84.58	84.21	83.84	83.48	83.11	82.71	82.33	81.95	81.56	81.17	80.81	80.39	79.98	79.58	79.17	78.75
752	84.81	84.43	84.07	83.71	83.34	82.94	82.55	82.17	81.78	81.40	81.02	80.61	80.20	79.80	79.39	78.97
754	85.04	84.66	84.29	83.93	83.56	83.16	82.78	82.39	82.00	81.62	81.25	80.83	80.42	80.01	79.60	79.18
756	85.26	84.89	84.52	84.16	83.79	83.39	83.00	82.62	82.22	81.84	81.47	81.05	80.64	80.23	79.83	79.40
758	85.49	85.12	84.75	84.38	84.01	83.61	83.22	82.84	82.44	82.06	81.69	81.27	80.86	80.45	80.04	79.62
760	85.72	85.34	84.97	84.61	84.24	83.84	83.45	83.06	82.67	82.28	81.91	81.48	81.08	80.67	80.26	79.83
762	85.95	85.57	85.20	84.84	84.46	84.06	83.67	83.29	82.89	82.50	82.13	81.70	81.30	80.89	80.48	80.05
764	86.18	85.80	85.42	85.06	84.69	84.28	83.90	83.51	83.11	82.72	82.35	81.92	81.52	81.11	80.70	80.27
766	86.41	86.03	85.65	85.29	84.91	84.51	84.12	83.73	83.33	82.94	82.57	82.14	81.74	81.32	80.91	80.49
768	86.63	86.25	85.88	85.51	85.14	84.73	84.34	83.95	83.55	83.17	82.79	82.36	81.96	81.54	81.13	80.70
770	86.86	86.48	86.11	85.74	85.36	84.96	84.57	84.17	83.78	83.39	83.01	82.58	82.17	81.76	81.35	80.92

Oxygen. Weight, in mgms., of Oxygen in 1 cc. of the Gas saturated with Aqueous Vapour. (Vanino).

mm.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°
700	1.253	1.248	1.242	1.237	1.231	1.225	1.219	1.214	1.208	1.202	1.196	1.190	1.184	1.178	1.172	1.165
702	1.257	1.251	1.246	1.240	1.234	1.229	1.223	1.217	1.211	1.205	1.200	1.194	1.188	1.181	1.175	1.169
704	1.260	1.255	1.249	1.244	1.238	1.232	1.227	1.221	1.215	1.209	1.203	1.197	1.191	1.185	1.179	1.172
706	1.264	1.259	1.253	1.247	1.241	1.236	1.230	1.224	1.218	1.212	1.207	1.201	1.194	1.188	1.182	1.176
708	1.268	1.262	1.256	1.251	1.245	1.239	1.234	1.228	1.222	1.216	1.210	1.204	1.198	1.192	1.186	1.179
710	1.271	1.266	1.260	1.254	1.249	1.243	1.237	1.231	1.225	1.219	1.214	1.208	1.202	1.195	1.189	1.183
712	1.275	1.269	1.264	1.258	1.252	1.247	1.241	1.235	1.229	1.223	1.217	1.211	1.205	1.199	1.192	1.186
714	1.279	1.273	1.267	1.262	1.256	1.250	1.244	1.239	1.233	1.227	1.221	1.215	1.208	1.202	1.196	1.190
716	1.282	1.277	1.271	1.265	1.259	1.254	1.248	1.242	1.236	1.230	1.224	1.218	1.212	1.206	1.199	1.193
718	1.286	1.280	1.274	1.269	1.263	1.257	1.251	1.245	1.240	1.234	1.228	1.221	1.215	1.209	1.203	1.196
720	1.289	1.284	1.278	1.272	1.267	1.261	1.255	1.249	1.243	1.237	1.231	1.229	1.219	1.213	1.206	1.200
722	1.293	1.287	1.282	1.276	1.270	1.264	1.259	1.253	1.247	1.241	1.235	1.229	1.222	1.216	1.210	1.203
724	1.297	1.291	1.285	1.280	1.274	1.268	1.262	1.256	1.250	1.244	1.238	1.232	1.226	1.220	1.213	1.207
726	1.300	1.295	1.289	1.283	1.277	1.271	1.266	1.260	1.254	1.248	1.242	1.236	1.229	1.223	1.217	1.210
728	1.304	1.298	1.292	1.287	1.281	1.275	1.269	1.263	1.257	1.251	1.245	1.239	1.233	1.226	1.220	1.213
730	1.308	1.302	1.296	1.290	1.284	1.279	1.273	1.267	1.261	1.255	1.249	1.243	1.236	1.230	1.224	1.217
732	1.311	1.306	1.300	1.294	1.288	1.282	1.276	1.270	1.264	1.258	1.252	1.246	1.240	1.233	1.227	1.221
734	1.315	1.309	1.303	1.298	1.292	1.286	1.280	1.274	1.268	1.262	1.256	1.250	1.243	1.237	1.231	1.224
736	1.318	1.313	1.307	1.301	1.295	1.289	1.283	1.277	1.271	1.265	1.259	1.253	1.247	1.240	1.234	1.227
738	1.322	1.316	1.310	1.305	1.299	1.293	1.287	1.281	1.275	1.269	1.263	1.256	1.250	1.244	1.237	1.231

mm.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°
740	1.326	1.320	1.314	1.308	1.302	1.296	1.290	1.285	1.278	1.272	1.266	1.260	1.254	1.247	1.241	1.234
742	1.329	1.324	1.318	1.312	1.306	1.300	1.294	1.289	1.281	1.276	1.270	1.263	1.257	1.251	1.244	1.238
744	1.333	1.327	1.321	1.315	1.309	1.304	1.298	1.292	1.285	1.279	1.273	1.266	1.261	1.254	1.248	1.241
746	1.337	1.331	1.325	1.319	1.313	1.307	1.301	1.295	1.289	1.283	1.277	1.270	1.264	1.258	1.251	1.245
748	1.340	1.334	1.328	1.323	1.317	1.311	1.305	1.299	1.292	1.286	1.280	1.274	1.267	1.261	1.255	1.248
750	1.344	1.338	1.332	1.326	1.320	1.314	1.308	1.302	1.296	1.290	1.284	1.277	1.271	1.264	1.258	1.252
752	1.347	1.342	1.336	1.330	1.324	1.318	1.312	1.306	1.300	1.293	1.287	1.281	1.274	1.268	1.261	1.255
754	1.351	1.345	1.339	1.333	1.327	1.321	1.315	1.309	1.303	1.297	1.291	1.284	1.278	1.272	1.265	1.258
756	1.355	1.349	1.343	1.337	1.331	1.325	1.319	1.313	1.307	1.300	1.294	1.288	1.282	1.275	1.269	1.262
758	1.358	1.352	1.346	1.341	1.334	1.329	1.322	1.316	1.310	1.304	1.298	1.291	1.285	1.279	1.272	1.265
760	1.362	1.356	1.350	1.344	1.338	1.332	1.326	1.320	1.314	1.307	1.301	1.295	1.288	1.282	1.276	1.269
762	1.366	1.360	1.354	1.348	1.342	1.336	1.350	1.323	1.317	1.311	1.304	1.298	1.292	1.285	1.279	1.272
764	1.369	1.363	1.357	1.351	1.345	1.339	1.333	1.327	1.321	1.314	1.308	1.302	1.295	1.289	1.282	1.276
766	1.373	1.367	1.361	1.355	1.349	1.343	1.337	1.331	1.324	1.318	1.312	1.305	1.299	1.292	1.286	1.279
768	1.377	1.371	1.365	1.359	1.353	1.346	1.340	1.334	1.328	1.322	1.315	1.309	1.302	1.296	1.289	1.283
770	1.380	1.374	1.368	1.362	1.356	1.350	1.344	1.338	1.331	1.325	1.319	1.312	1.306	1.299	1.293	1.286

Nitrogen. Weight, in mgms., of Nitrogen in 1 cc. of Gas measured saturated with Water Vapour at the given temperature and pressure. (Gattermann).

mm.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°
720	1.128	1.123	1.118	1.113	1.108	1.103	1.098	1.093	1.088	1.082	1.077	1.072	1.066	1.061	1.055	1.050
722	1.132	1.126	1.122	1.117	1.111	1.106	1.101	1.096	1.091	1.086	1.080	1.075	1.069	1.064	1.058	1.053
724	1.135	1.130	1.125	1.120	1.114	1.109	1.104	1.099	1.094	1.089	1.083	1.078	1.073	1.067	1.061	1.056
726	1.138	0.133	1.128	1.123	1.118	1.113	1.107	1.102	1.097	1.092	1.086	1.081	1.076	1.070	1.064	1.059
728	1.141.	1.136	1.131	1.126	1.121	1.116	1.111	1.105	1.100	1.095	1.089	1.084	1.079	1.073	1.067	1.062
730	1.144	1.139	1.134	1.129	1.124	1.119	1.114	1.108	1.103	1.098	1.092	1.087	1.082	1.076	1.070	1.065
732	1.147	1.142	1.137	1.132	1.127	1.122	1.117	1.111	1.106	1.101	1.095	1.090	1.085	1.079	1.073	1.068
734	1.151	1.145	1.140	1.135	1.130	1.125	1.120	1.115	1.109	1.104	1.099	1.093	1.088	1.082	1.076	1.071
736	1.154	1.149	1.144	1.139	1.133	1.128	1.123	1.118	1.112	1.107	1.102	1.096	1.091	1.085	1.080	1.074
738	1.157	1.152	1.147	1.142	1.136	1.131	1.126	1.121	1.116	1.110	1.105	1.099	1.094	1.088	1.083	1.077
740	1.160	1.155	1.150	1.145	1.140	1.134	1.129	1.124	1.119	1.113	1.108	1.102	1.097	1.091	1.086	1.080
742	1.163	1.158	1.153	1.148	1.143	1.137	1.132	1.127	1.122	1.116	1.111	1.105	1.100	1.094	1.089	1.083
744	1.166	1.161	1.156	1.151	1.146	1.141	1.135	1.130	1.125	1.119	1.114	1.108	1.103	1.097	1.092	1.086
746	1.170	1.164	1.159	1.154	1.149	1.144	1.138	1.133	1.128	1.122	1.117	1.111	1.106	1.100	1.095	1.089
748	1.173	1.168	1.163	1.157	1.152	1.147	1.142	1.136	1.131	1.126	1.120	1.115	1.109	1.103	1.098	1.092
750	1.176	1.171	1.166	1.161	1.155	1.150	1.145	1.139	1.134	1.129	1.123	1.118	1.112	1.106	1.101	1.095
752	1.179	1.174	1.169	1.164	1.158	1.153	1.148	1.143	1.137	1.132	1.126	1.121	1.115	1.109	1.104	1.098
754	1.182	1.177	1.172	1.167	1.161	1.156	1.151	1.146	1.140	1.135	1.129	1.124	1.118	1.112	1.107	1.101
756	1.186	1.180	1.175	1.170	1.165	1.159	1.154	1.149	1.143	1.138	1.132	1.127	1.121	1.115	1.110	1.104
758	1.189	1.183	1.178	1.173	1.168	1.162	1.157	1.152	1.146	1.141	1.135	1.130	1.124	1.119	1.113	1.107
760	1.192	1.187	1.181	1.176	1.171	1.166	1.160	1.155	1.149	1.144	1.138	1.133	1.127	1.122	1.116	1.110
762	1.195	1.190	1.185	1.179	1.174	1.169	1.163	1.158	1.153	1.147	1.141	1.136	1.130	1.125	1.119	1.113
764	1.198	1.193	1.188	1.182	1.177	1.172	1.166	1.161	1.156	1.150	1.145	1.139	1.133	1.128	1.122	1.116
766	1.201	1.196	1.191	1.186	1.180	1.175	1.170	1.164	1.159	1.153	1.148	1.142	1.136	1.131	1.125	1.119
768	1.205	1.199	1.194	1.189	1.183	1.178	1.173	1.167	1.162	1.156	1.151	1.145	1.139	1.134	1.128	1.122
770	1.208	1.202	1.197	1.192	1.187	1.181	1.176	1.170	1.165	1.159	1.154	1.148	1.143	1.137	1.131	1.125

SOLUBILITIES.

I. Gases in Liquids.

The amount of gas dissolved (absorbed) by a liquid is directly proportional to the pressure (Dalton's or Henry's law), provided that no chemical combination occurs between the solute and the solvent. In the case of a gas mixture, the gases dissolve in proportion to their respective partial pressures, *i.e.* the pressure each gas would exert respectively if it occupied the entire volume available instead of a part corresponding to its percentage by volume.

The *Absorption Coefficient*, α, of a gas gives the volume of gas (calculated to N.T.P.) absorbed by 1 volume of liquid at a certain temperature when the partial pressure of the gas is 760 mm.

The symbol, **q**, represents grams of gas dissolved by 100 grams of solvent when the total pressure (= partial pressure of gas + partial pressure of vapour of solvent) is 760 mm.

α^1 represents vols. of gas absorbed by 1 vol. liquid at temperature when total pressure is 760 mm.

Solubility of the Constituents of Dry Air (free from CO_2 and NH_3) in Water. (Winkler, 1904).

	1 litre water contains cc. gas (N.T.P.)				1 litre water contains cc. gas (N.T.P.).		
°C.	O_2	N_2, etc.	%O_2 in dissd. gas	°C.	O_2	N_2, etc.	%O_2 in dissd. gas
0	10.19	18.99	34.91	16	6.89	13.25	34.21
1	9.91	18.51	34.87	17	6.75	13.00	34.17
2	9.64	18.05	34.82	18	6.61	12.77	34.12
3	9.39	17.60	34.78	19	6.48	12.54	34.08
4	9.14	17.18	34.74	20	6.36	12.32	34.03
5	8.91	16.77	34.69	21	6.23	12.11	33.99
6	8.68	16.38	34.65	22	6.11	11.90	33.95
7	8.47	16.00	34.60	23	6.00	11.69	33.90
8	8.26	15.64	34.56	24	5.89	11.49	33.86
9	8.06	15.30	34.52	25	5.78	11.30	33.82
10	7.87	14.97	34.47	26	5.67	11.12	33.77
11	7.69	14.65	34.43	27	5.56	10.94	33.73
12	7.52	14.35	34.38	28	5.46	10.75	33.68
13	7.35	14.06	34.34	29	5.36	10.56	33.64
14	7.19	13.78	34.30	30	5.26	10.38	33.60
15	7.04	13.51	34.25				

Solubility of Atmospheric Oxygen in Water.
(T. Carlson, 1913).

°C.	cc. per lit.	°C.	cc. per lit.	°C.	cc. per lit.
0	10.26	10	8.02	20	6.55
5	9.02	15	7.21	25	6.00

Solubilities, α, of Gases in Water.

°C	(Bunsen) Air.	(Raoult, 1874) NH_3.	(Geffcken, 1904). N_2O.	(Winkler, 1901). NO.	(Winkler, 1901). CO.	(Winkler, 1901). CH_4.	(Winkler, 1901). C_2H_6.	(Winkler, unpublished, 1912). C_2H_4
0	0.02471	1305	—	0.07381	0.03537	0.05563	0.09814	0.226
1	406	1225	—	171	3455	5401	9476	.219
2	345	1165	—	0.06981	3375	5244	9093	.211
3	287	1107	—	801	3297	5093	8725	.204
4	237	1058	—	628	3233	4946	8372	.197
5	179	1024	1.0480	461	3149	4805	8033	.191
6	.128	1002	1.0140	300	3078	4669	7709	.184
7	080	980.2	0.9800	144	3009	4539	7400	.178
8	034	959.5	.9459	0.05994	2943	4413	7106	.173
9	0.01992	937.5	.9118	849	2878	4292	6826	.167
10	953	915.5	.8778	709	2816	4177	6561	.162
11	916	892.1	.8518	575	2757	4072	6328	.157
12	882	870.1	.8218	453	2701	3970	6106	.152
13	851	848.1	.7937	343	2646	3872	5894	.148
14	822	826.1	.7658	241	2593	3779	5694	.143
15	795	806.7	.7378	147	2543	3690	5504	.139
16	771	787.4	.7162	056	2494	3606	5326	.136
17	750	768.0	.6944	0.04967	2448	3525	5159	.132
18	732	748.8	.6727	880	2402	3448	5003	.129
19	717	730.8	.6510	793	2360	3376	4858	.125
20	701	715.4	.6294	706	2319	3308	4724	.122
21	—	694.7	.6123	—	2281	3243	4589	.119
22	—	678.3	.5954	—	2244	3180	4459	.116
23	—	665.6	.5783	—	2208	3119	4335	.114
24	—	653.0	.5614	—	2174	3061	4217	.111
25	—	640.5	.5443	323	2142	3006	4104	.108

Solubility of Hydrogen in Water.
(Winkler, 1891.)

°C.	α	°C.	α	°C.	α
0	0.02148	11	0.01940	30	0.019699
1	126	12	925	35	666
2	105	13	911	40	644
3	084	14	897	45	624
4	064	15	883	50	608
5	044	16	869	60	600
6	025	17	856	70	600
7	007	18	844	80	600
8	0.01989	19	831	90	600
9	972	20	819	100	600
10	955	25	754		

Solubility of Oxygen and Nitrogen in Water.
(Fox, 1909).

°C.	Oxygen. α	Nitrogen. α	°C.	Oxygen. α	Nitrogen. α
0	0.04924	0.02300	26	0.02842	0.01423
1	4794	2250	27	2794	1404
2	4665	2202	28	2751	1387
3	4545	2155	29	2708	1371
4	4431	2109	30	2665	1355
5	4321	2064	31	2627	1339
6	4215	2020	32	2590	1323
7	4115	0.01977	33	2554	1308
8	4019	1935	34	2519	1293
9	0.03928	1894	35	2485	1279
10	3837	1854	36	2452	1265
11	3751	1816	37	2420	1252
12	3675	1780	38	2389	1239
13	3598	1746	39	2359	1227
14	3526	1714	40	2330	1215
15	3455	1684	41	2302	1204
16	3388	1656	42	2275	1192
17	3321	1629	43	2249	1180
18	3258	1603	44	2224	1168
19	3201	1578	45	2200	1157
20	3144	1554	46	2177	1146
21	3091	1529	47	2155	1135
22	3038	1506	48	2134	1124
23	0.02986	1484	49	2114	1113
24	2938	1463	50	2095	1102
25	2890	1443			

Solubilities, α, of Rare Gases in Water.
(von Antropoff, 1919).

°C.	Helium.	Neon.	Argon.	Krypton.	Xenon.	Radium Emanation.
0	0.0097	0.0114	0.0578	0.1105	0.242	0.510
10	.0099	.0118	.0452	.0810	.174	.326
20	.0100	.0147	.0374	.0626	.123	.222
30	.0101	.0155	.0326	.0511	.098	.162
40	.0103	.0217	.0286	.0433	.082	.126
50	.0108	.0322	.0257	.0383	.073	.100
60	—	—	—	.0357	—	.085

Solubility of Ammonia in Water.
(Roscoe and Dittmar, 1859).

°C.	q	°C.	q	°C.	q	°C.	q	°C.	q	°C.	q
0	87.5	10	67.9	20	52.6	30	40.3	40	30.7	60	22.9
2	83.3	12	64.5	22	49.9	32	38.2	42	29.0	52	21.4
4	79.2	14	61.2	24	47.4	34	36.2	44	27.5	54	20.0
6	75.1	16	58.2	26	44.9	36	34.3	46	25.9	56	18.6
8	71.3	18	55.4	28	42.6	38	32.4	48	24.4		

Solubility of Carbon Dioxide in Water.
(Bohr and Bock, 1891).

°C.	α	q	°C.	α	q	°C.	α	q
0	1.713	0.3347	12	1.117	0.2166	24	0.781	0.1494
1	1.646	214	13	1.083	099	25	0.759	450
2	1.584	091	14	1.050	033	26	0.738	407
3	1.527	0.2979	15	1.019	0.1971	27	0.718	367
4	1.473	872	16	0.985	904	28	0.699	328
5	1.424	774	17	0.956	845	29	0.682	293
6	1.377	681	18	0.928	789	30	0.665	250
7	1.331	590	19	0.902	736	35	0.592	106
8	1.282	494	20	0.878	689	40	0.530	0.0974
9	1.237	404	21	0.854	641	45	0.479	862
10	1.194	319	22	0.829	591	50	0.436	762
11	1.154	240	23	0.804	541	60	0.359	577

Solubility of Chlorine in Water. (Winkler, 1907).
(a_1 for total pressure of 760 mm.)

°C.	a_1	q	°C.	a_1	q	°C.	a_1	q
10	3.095	0.9969	20	2.260	0.7291	30	1.769	0.5722
11	2.996	0.9652	21	2.200	0.7098	35	1.575	0.5103
12	2.900	0.9344	22	2.143	0.6916	40	1.414	0.4589
13	2.808	0.9048	23	2.087	0.6737	45	1.300	0.4227
14	2.720	0.8766	24	2.035	0.6570	50	1.204	0.3927
15	2.635	0.8493	25	1.985	0.6411	60	1.006	0.3294
16	2.553	0.8230	26	1.937	0.6257	70	0.848	0.2792
17	2.474	0.7977	27	1.891	0.6110	80	0.672	0.2226
18	2.399	0.7736	28	1.848	0.5973	90	0.380	0.1268
19	2.328	0.7508	29	1.808	0.5845	100	0.000	0.0000

Solubility of Hydrobromic Acid in Water.
(Roozeboom, 1885).
(a_1 for total pressure of 760 mm.)

°C.	a_1	q	°C.	a_1	q	°C.	a_1	q
− 25	–	255.0	− 5	630.0	228.0	50	468.6	171.2
− 20	–	247.3	0	611.6	221.2	75	406.7	150.5
− 12	–	239.0	+10	581.4	210.3	100	344.6	130.0
− 10	644.5	233.5	25	582.1	193.0			

Solubility of Hydrochloric Acid in Water.
(Roscoe and Dittmar, 1859).
(a_1 for total pressure of 760 mm.)

°C.	a_1	q	°C.	a_1	q	°C.	a_1	q
0	506.5	82.5	22	435.0	71.0	44	–	61.8
2	499.8	81.4	24	428.7	70.0	46	–	61.1
4	493.7	80.4	26	423.0	69.1	48	–	60.3
6	486.9	79.3	28	417.2	68.2	50	361.6	59.6
8	480.8	78.3	30	411.5	67.3	52	–	58.9
10	473.9	77.2	32	–	66.5	54	–	58.2
12	467.7	76.2	34	–	65.7	56	–	57.5
14	461.5	75.2	36	–	64.9	58	–	56.8
16	455.2	74.2	38	–	64.1	60	338.7	56.1
18	448.3	73.1	40	385.7	63.3			
20	442.0	72.1	42	–	62.6			

Solubility of Hydrogen Sulphide in Water.
(Winkler, 1907).

°C.	a	°C.	a	°C.	a	°C.	a
0	4.621	8	3.578	16	2.834	24	2.312
1	4.475	9	3.468	17	2.759	25	2.257
2	4.333	10	3.362	18	2.687	26	2.204
3	4.196	11	3.265	19	2.619	27	2.153
4	4.063	12	3.172	20	2.554	28	2.105
5	3.935	13	3.082	21	2.491	29	2.058
6	3.811	14	2.996	22	2.429	30	2.014
7	3.692	15	2.913	23	2.370		

Solubility of Sulphur Dioxide in Water.
(Schönfeld, 1855).

°C.	a	°C.	a	°C.	a	°C.	a
0	79.789	11	54.655	22	36.617	33	24.244
1	77.210	12	52.723	23	35.302	34	23.347
2	74.691	13	50.849	24	34.026	35	22.489
3	72.230	14	49.033	25	32.786	36	21.668
4	69.828	15	47.276	26	31.584	37	20.886
5	67.485	16	45.578	27	30.422	38	20.141
6	65.200	17	43.939	28	29.314	39	19.435
7	62.973	18	42.360	29	28.210	40	18.766
8	60.805	19	40.838	30	27.161		
9	58.697	20	39.374	31	26.151		
10	56.647	21	37.970	32	25.178		

Solubility of Oxygen in Alcohol.
(Timofejeff, 1890).

°C.	a	°C.	a	°C.	a	°C.	a
0	0.23370	7	0.22863	14	0.22389	21	0.21946
1	296	8	793	15	324	22	886
2	222	9	724	16	259	23	826
3	149	10	656	17	195	24	767
4	077	11	588	18	132		
5	005	12	521	19	069		
6	0.22934	13	455	20	007		

Solubilities, α, of Gases in Alcohol.   (Carius;* Bunsen).

°C.	Hydrogen.	Nitrogen.	N₂O	NO	CO₂	CH₄	C₂H₄	H₂S	SO₂*
0	0.06925	0.12634	4.1780	0.31606	4.3295	0.52259	3.5960	17.891	328.62
1	910	593	4.1088	1262	4.2368	1973	3.5379	17.242	311.98
2	886	553	4.0409	0.30928	4.1466	1691	3.4823	16.606	295.97
3	881	514	3.9741	604	4.0589	1412	3.4280	15.983	280.58
4	867	476	3.9085	290	3.9736	1135	3.3750	15.373	265.81
5	863	440	3.8442	0.29985	3.8908	0861	3.3234	14.776	251.67
6	839	405	3.7811	690	3.8105	0590	3.2732	14.193	238.16
7	826	371	3.7192	405	3.7327	0322	3.2245	13.623	225.25
8	813	338	3.6585	130	3.6673	0057	3.1768	13.066	212.98
9	799	306	3.5990	0.28865	3.5844	0.49795	3.1307	12.523	201.33
10	786	276	3.5408	609	3.5140	9535	3.0859	11.992	190.31
11	774	247	3.4838	363	3.4461	9278	3.0425	11.475	179.91
12	761	219	3.4279	127	3.3807	9024	3.0005	10.971	170.13
13	749	192	3.3734	0.27901	3.3178	8773	2.9598	10.480	160.98
14	737	166	3.3200	685	3.2573	8525	2.9205	10.003	152.45
15	725	142	3.2678	478	3.1993	8280	2.8825	9.539	144.55
16	713	119	3.2169	281	3.1438	8037	2.8459	9.088	137.27
17	701	097	3.1672	094	3.0908	7798	2.8107	8.650	130.61
18	690	076	3.1187	0.26917	3.0402	7561	2.7768	8.225	124.58
19	679	056	3.0714	750	2.9921	7327	2.7443	7.814	119.17
20	668	038	3.0253	592	2.9465	7096	2.7131	7.415	114.48
21	657	021	2.9805	444	2.9034	6867	2.6833	7.030	110.22
22	646	005	2.9368	306	2.8628	6642	2.6549	6.659	106.68
23	636	0.11990	2.8944	178	2.8247	6419	2.6279	6.300	103.77
24	626	976	2.8532	060	2.7890	6199	2.6022	5.955	101.47
25	616	964	2.8133	0.25951	2.7558	5982	2.5778	5.623	99.81

II. Solids in Liquids.

The solubility of solids depends mainly on the temperature, but is also influenced by the nature of a substance (its source, treatment, degree of hydration, etc.) and to a small extent by the pressure.

In the following tables W = grms. of substance in 100 grms. water, S = grms. of substance in 100 grms. solution.

The volume of a solution is generally smaller than the sum of the volumes of the constituents (*e.g.* alcohol and water), but exceptions are known (*e.g.* alcohol and carbon disulphide).

Unless otherwise stated, the solvent is water.

Solubility of Aluminium Sulphate. (Poggiale, 1843).

°C.	$Al_2(SO_4)_3$ W.	$Al_2(SO_4)_3.18H_2O$ W.	°C.	$Al_2(SO_4)_3$ W.	$Al_2(SO_4)_3.18H_2O$ W.
0	31.3	86.85	60	59.1	262.6
10	33.5	95.8	70	66.23	348.2
20	36.15	107.35	80	73.1	467.3
30	40.36	127.6	90	80.8	678.8
40	45.73	167.6	100	89.11	1132.0
50	52.13	201.4			

Solubility of Ammonia Alum. (Poggiale, 1843).

°C.	Anhydrous. W.	Crystals with $24H_2O$ W.	°C.	Anhydrous. W.	Crystals with $24H_2O$ W.
0	2.10	3.90	25	9.19	19.19
5	3.50	6.91	30	10.94	22.01
10	4.99	9.52	40	14.88	30.92
15	6.25	12.66	50	20.10	44.10
20	7.74	15.13	60	26.70	66.65

Solubility of Ammonium Nitrate.
(Muller and Kaufmann, 1903).

°C.	W. (NH_4NO_3)	°C.	W. (NH_4NO_3)
0	118.3	40	297
12.2	153.4	50	344
20.2	192.4	60	421
25.0	214.2	70	499
30.0	241.8	80	580
32.1	256.9	90	740
35.0	265.8	100	871

Solubility of Ammonium Chloride (Mulder).

°C.	$\dfrac{NH_4Cl.}{W.}$	°C.	$\dfrac{NH_4Cl.}{W.}$	°C.	$\dfrac{NH_4Cl.}{W.}$
0	29.7	39	45.3	78	64.5
1	30.0	40	45.8	79	65.1
2	30.3	41	46.2	80	65.6
3	30.6	42	46.7	81	66.2
4	31.0	43	47.1	82	66.7
5	31.4	44	47.6	83	67.3
6	31.8	45	48.0	84	67.8
7	32.2	46	48.5	85	68.4
8	32.6	47	49.0	86	69.0
9	33.0	48	49.5	87	69.6
10	33.3	49	49.9	88	70.2
11	33.7	50	50.4	89	70.7
12	34.1	51	50.9	90	71.3
13	34.5	52	51.3	91	71.9
14	34.8	53	51.8	92	72.5
15	35.2	54	52.3	93	73.1
16	35.6	55	52.8	94	73.7
17	36.0	56	53.2	95	74.3
18	36.4	57	53.7	96	74.9
19	36.8	58	54.2	97	75.5
20	37.2	59	54.7	98	76.1
21	37.6	60	55.2	99	76.7
22	38.0	61	55.7	100	77.3
23	38.4	62	56.2	101	78.0
24	38.8	63	56.7	102	78.6
25	39.3	64	57.2	103	79.2
26	39.7	65	57.7	104	79.9
27	40.1	66	58.2	105	80.5
28	40.5	67	58.7	106	81.2
29	40.9	68	59.2	107	81.8
30	41.4	69	59.7	108	82.5
31	41.8	70	60.2	109	82.1
32	42.2	71	60.7	110	83.8
33	42.7	72	61.2	111	84.4
34	43.1	73	61.7	112	85.1
35	43.6	74	62.2	113	85.7
36	44.0	75	62.8	114	86.4
37	44.4	76	63.4	115	87.1
38	44.9	77	63.9	115.65	87.3

Solubility of Ammonium Sulphate. (Mulder).

°C.	$\frac{(NH_4)_2SO_4}{W.}$	°C.	$\frac{(NH_4)_2SO_4}{W.}$	°C.	$\frac{(NH_4)_2SO_4}{W.}$
0	70.6	37	80.1	74	93.1
1	70.9	38	80.4	75	93.4
2	71.1	39	80.7	76	93.8
3	71.4	40	81.0	77	94.2
4	71.6	41	81.3	78	94.5
5	71.8	42	81.7	79	94.9
6	72.1	43	82.0	80	95.3
7	72.3	44	82.3	81	95.6
8	72.5	45	82.7	82	96.0
9	72.8	46	83.0	83	96.4
10	73.0	47	83.3	84	96.8
11	73.2	48	83.7	85	97.2
12	73.5	49	84.0	86	97.6
13	73.7	50	84.4	87	98.0
14	74.0	51	84.7	88	98.4
15	74.2	52	85.1	89	98.8
16	74.4	53	85.5	90	99.2
17	74.7	54	85.8	91	99.6
18	74.9	55	86.2	92	100.0
19	75.1	56	86.6	93	100.4
20	75.4	57	86.9	94	100.8
21	75.7	58	87.3	95	101.2
22	75.9	59	87.7	96	101.6
23	76.2	60	88.0	97	102.1
24	76.4	61	88.4	98	102.5
25	76.7	62	88.7	99	102.9
26	76.9	63	89.1	100	103.3
27	77.2	64	89.5	101	103.8
28	77.5	65	89.9	102	104.2
29	77.8	66	90.2	103	104.6
30	78.0	67	90.6	104	105.1
31	78.3	68	90.9	105	105.5
32	78.6	69	91.3	106	106.0
33	78.9	70	91.6	107	106.5
34	79.2	71	92.0	108	107.0
35	79.5	72	92.4	108.9	107.6
36	79.8	73	92.7		

Solubility of Ammonium Thiocyanate.

	W.	
0°C.	128.1	$(NH_4)CNS$
20°C.	162.2	,,

Solubility of Arsenious Oxide.

Crystallised modification (Bruner and St. Tolloczko 1903).		Amorphous modification. (Winkler).
°C.	Grms. As_2O_3 in 100 cc. soln.	Grms. As_2O_3 in 100 cc. water.
2	1.201	Ord. temp.	3.7
15	1.657	B.Pt.	11.86
25	2.038		
39.8	2.930		

Solubility of Barium Chlorate.
(Trautz and Auschütz, 1906).

	$Ba(ClO_3)_2$.			$Ba(ClO_3)_2$.	
°C.	S.	W.	°C.	S.	W.
0	16.90	20.40	50	36.69	57.95
10	21.23	26.94	60	40.05	66.80
20	25.26	33.80	70	43.04	75.56
25	27.53	37.99	80	45.90	84.84
30	29.43	41.70	90	48.70	94.93
40	33.16	49.61	100	51.17	104.80

Solubility of Barium Hydroxide.
(Rosenstiehl 1870).

°C.	$Ba(OH)_2$ W.	$Ba(OH)_2.8H_2O$ W.	°C.	$Ba(OH)_2$ W.	$Ba(OH)_2.8H_2O$ W.
0	1.5	-	45	9.12	-
5	1.75	-	50	11.75	-
10	2.21	4.69	55	14.71	-
15	2.89	-	60	18.76	48.08
20	3.48	7.43	65	24.67	-
25	4.19	-	70	31.9	-
30	5.0	-	75	56.85	-
35	6.17	-	78.5	94.74	-
40	7.36	16.42	80	90.77	38.46

Solubility of Barium Chloride.   (Mulder).

°C.	$BaCl_2$ W.	°C.	$BaCl_2$ W.	°C.	$BaCl_2$ W.
0	30.9	36	39.7	72	50.0
1	31.2	37	40.0	73	50.3
2	31.5	38	40.2	74	50.6
3	31.7	39	40.5	75	50.9
4	31.9	40	40.7	76	51.2
5	32.2	41	41.0	77	51.5
6	32.4	42	41.3	78	51.8
7	32.6	43	41.6	79	52.1
8	32.8	44	41.9	80	52.4
9	33.1	45	42.2	81	52.7
10	33.3	46	42.5	82	53.0
11	33.5	47	42.7	83	53.3
12	33.8	48	43.0	84	53.6
13	34.0	49	43.3	85	54.0
14	34.2	50	43.6	86	54.3
15	34.5	51	43.9	87	54.6
16	34.7	52	44.2	88	55.0
17	35.0	53	44.4	89	55.3
18	35.2	54	44.7	90	55.6
19	35.5	55	45.0	91	55.9
20	35.7	56	45.3	92	56.2
21	36.0	57	45.6	93	56.6
22	36.2	58	45.9	94	56.9
23	36.5	59	46.2	95	57.2
24	36.7	60	46.4	96	57.6
25	37.0	61	46.7	97	57.9
26	37.2	62	47.0	98	58.2
27	37.5	63	47.3	99	58.5
28	37.7	64	47.6	100	58.8
29	38.0	65	47.9	101	59.2
30	38.2	66	48.2	102	59.5
31	38.5	67	48.5	103	59.8
32	38.7	68	48.8	104	60.2
33	39.0	69	49.1	104.1	60.3
34	39.2	70	49.4		
35	39.5	71	49.7		

Solubility of Benzoic Acid and Salicylic Acid.
(Bourgoin, 1878).

°C.	C_6H_5COOH W.	$C_6H_4(OH)COOH$ W.	°C.	C_6H_5COOH W.	$C_6H_4(OH)COOH$ W.
0	0.170	0.150	40	0.555	0.555
5	0.185	0.165	45	0.650	0.665
10	0.210	0.190	50	0.775	0.800
15	0.245	0.225	55	0.940	0.980
20	0.290	0.270	60	1.155	1.225
25	0.345	0.325	65	1.430	1.555
30	0.410	0.390	70	1.775	1.990
35	0.480	0.465	75	2.200	2.550

Solubility of Borax. (Horn and van Wagener, 1903)

°C.	Anhydrous salt. S.	W.	°C.	Anhydrous salt. S.	W.
0	†1.3	†1.3	*60	16.7	20.0
5	1.3	1.3	65	18.0	21.9
10	1.6	1.6	70	19.6	24.4
30	3.7	3.9	80	23.9	31.4
45	7.5	8.1	90	29.0	40.8
50	9.5	10.5	100	34.3	52.2
55	12.4				

* Transition point Hydrate 10 aq. + 5 aq.

† These values from Mulder.

E

Solubility of Boric Acid. (Nasini and Ageno, 1909).

°C.	H_3BO_3 S.	B_2O_3 W.		°C.	H_3BO_3 S.	B_2O_3 W.
0	2.52	2.59		55	10.34	11.53
5	2.98	3.08		60	11.42	12.90
10	3.46	3.59		65	12.47	14.25
15	4.03	4.19		70	13.60	15.75
20	4.38	4.79		75	14.67	17.20
25	5.17	5.45		80	16.04	19.11
30	5.89	6.25		85	17.45	21.15
35	6.65	7.12		90	18.97	23.30
40	7.42	8.02		95	20.39	25.62
45	8.41	9.18		99.5	21.93	28.10
50	9.37	10.35				

Solubility of Calcium Chloride. (Roozeboom, 1889).

°C.	$CaCl_2$ S.	W.		°C.	$CaCl_2$ S.	W.
– 25	33.3	49.9		70	58.6	141.6
20	34.1	51.8		75	59.0	143.9
15	34.9	53.6		80	59.5	146.9
10	35.7	55.6		85	59.9	149.4
5	36.5	57.5		90	60.4	152.5
0	37.3	59.5		95	60.9	155.8
+5	38.0	61.3		100	61.4	159.1
10	39.4	65.0		105	62.0	163.2
15	40.6	68.4		110	62.4	166.0
20	42.7	74.5		115	62.9	169.5
25	46.2	85.9		120	63.4	173.2
*(i) 29.8	50.1	100.4		125	63.9	177.0
30	50.2	100.8		130	64.5	181.7
35	51.8	107.5		135	65.0	185.7
40	53.5	115.3		140	65.6	190.7
45	56.4	130.4		145	66.4	197.6
*(ii) 45.3	56.6	129.4		150	67.3	205.8
50	57.0	132.6		155	68.1	213.5
55	57.4	134.7		160	69.0	222.6
60	57.8	136.8		161.5	69.4	226.8
65	58.2	139.3				

* Transition point for (i) Hydrate with 6 aq. + 4 aq. (a); (ii) Hydrate with 4 aq. + 2 aq.

Solubility of Calcium Hydroxide. (Maben 1883).

°C.	CaO W.	°C.	CaO W.	°C.	CaO W.
0	0.131	40	0.107	80	0.073
10	0.129	50	0.098	90	0.063
20	0.126	60	0.088	100	0.060
30	0.116	70	0.080		

Solubility of Cane Sugar. (Herzfeld, 1892).

°C.	Cane sugar. S.	W.	°C.	Cane sugar. S.	W.
0	64.18	179.2	28	68.37	216.3
1	64.31	180.3	29	68.53	217.9
2	64.45	181.4	30	68.70	219.5
3	64.59	182.5	31	68.87	221.3
4	64.73	183.6	32	69.04	223.1
5	64.87	184.7	33	69.21	224.8
6	65.01	185.8	34	69.38	226.6
7	65.15	187.0	35	69.55	228.4
8	65.29	188.2	36	69.72	230.3
9	65.43	189.3	37	69.89	232.3
10	65.58	190.5	38	70.06	234.2
11	65.73	191.8	39	70.24	236.1
12	65.88	193.1	40	70.42	238.1
13	66.03	194.4	41	70.60	240.2
14	66.18	195.7	42	70.78	242.3
15	66.33	197.0	43	70.96	244.4
16	66.48	198.4	44	71.14	246.6
17	66.63	199.7	45	71.32	248.7
18	66.78	201.1	46	71.50	251.0
19	66.93	202.5	47	71.68	253.3
20	67.09	203.9	48	71.87	255.7
21	67.25	205.4	49	72.06	258.0
22	67.41	206.9	50	72.25	260.4
23	67.57	208.4	51	72.44	262.9
24	67.73	209.9	52	72.63	265.5
25	67.89	211.4	53	72.82	268.0
26	68.05	213.0	54	73.01	270.6
27	68.21	214.7	55	73.20	273.1

°C.	Cane sugar.		°C.	Cane sugar.	
	S.	W.		S.	W.
56	73.39	276.0	79	78.14	357.6
57	73.58	278.8	80	78.36	362.1
58	73.78	281.6	81	78.58	367.1
59	73.98	284.5	82	78.80	372.0
60	74.18	287.3	83	79.02	376.9
61	74.38	290.4	84	79.24	381.9
62	74.58	293.5	85	79.46	386.(
63	74.78	296.7	86	79.69	392.5
64	74.98	299.8	87	79.92	398.4
65	75.18	302.9	88	80.15	404.2
66	75.38	306.4	89	80.38	409.9
67	75.59	310.0	90	80.61	415.7
68	75.80	313.5	91	80.84	422.3
69	76.01	317.0	92	81.07	428.8
70	76.22	320.4	93	81.30	435.4
71	76.43	324.4	94	81.53	442.0
72	76.64	328.3	95	81.77	448.0
73	76.85	332.2	96	82.01	456.3
74	77.06	336.0	97	82.25	464.0
75	77.27	339.9	98	82.49	471.7
76	77.48	344.4	99	82.73	479.4
77	77.70	348.8	100	82.97	487.2
78	77.92	353.2			

Solubility of Cobalt Ammonium Sulphate.
(Tobler 1855).

°C.	$CoSO_4.(NH_4)_2SO_4$ W.	°C.	$CoSO_4.(NH_4)_2SO_4$ W.
0	8.9	40	22.3
10	11.6	45	25
18	15.2	50	28.7
23	17.1	60	34.5
35	19.6	75	43.3

Solubility of Cobalt Sulphate. (Mulder 1864).

°C.	$CoSO_4$ W.	°C.	$CoSO_4$ W.	°C.	$CoSO_4$ W.
0	24.6	34	42.4	68	62.6
1	25.0	35	42.9	69	63 2
2	25.5	36	43.5	70	63.8
3	26.0	37	44.0	71	64.4
4	26.5	38	44.6	72	65.0
5	27.0	39	45.2	73	65.6
6	27.5	40	45.8	74	66.2
7	28.0	41	46.4	75	66.8
8	28.5	42	47.0	76	67.4
9	29.0	43	47.6	77	68.0
10	29.5	44	48.2	78	68.6
11	30.0	45	48.8	79	69.2
12	30.5	46	49.4	80	69.8
13	31.0	47	50.0	81	70.4
14	31.5	48	50.6	82	71.0
15	32.0	49	51.2	83	71.6
16	32.5	50	51.8	84	72.2
17	33.0	51	52.4	85	72.8
18	33.5	52	53.0	86	73.4
19	34.0	53	53.6	87	74.0
20	34.5	54	54.2	88	74.6
21	35.1	55	54.8	89	75.2
22	35.6	56	55.4	90	75.9
23	36.2	57	56.0	91	76.6
24	36.8	58	56.6	92	77.2
25	37.4	59	57.2	93	77.9
26	38.0	60	57.8	94	78.6
27	38.5	61	58.4	95	79.2
28	39.1	62	59.0	96	79.9
29	39.6	63	59.6	97	80.6
30	40.2	64	60.2	98	81.3
31	40.7	65	60.8	99	81.9
32	41.3	66	61.4	100	82.6
33	41.8	67	62.0		

Solubility of Copper Sulphate. (Mulder).

°C.	$CuSO_4$ W.	°C.	$CuSO_4$ W.	°C.	$CuSO_4$ W.
0	15.5	35	27.5	70	45.7
1	16.3	36	27.9	71	46.4
2	16.6	37	28.3	72	47.2
3	16.9	38	28.7	73	47.9
4	17.2	39	29.1	74	48.7
5	17.5	40	29.5	75	49.5
6	17.8	41	29.9	76	50.3
7	18.1	42	30.3	77	51.1
8	18.4	43	30.7	78	51.9
9	18.7	44	31.1	79	52.7
10	19.1	45	31.5	80	53.5
11	19.3	46	31.9	81	54.3
12	19.6	47	32.3	82	55.1
13	19.9	48	32.7	83	55.9
14	20.2	49	33.2	84	56.8
15	20.5	50	33.6	85	57.8
16	20.8	51	34.1	86	58.7
17	21.1	52	34.5	87	59.7
18	21.4	53	35.0	88	60.7
19	21.7	54	35.5	89	61.7
20	22.0	55	36.0	90	62.7
21	22.3	56	36.6	91	63.7
22	22.6	57	37.2	92	64.8
23	23.0	58	37.8	93	65.8
24	23.3	59	38.4	94	66.9
25	23.7	60	39.0	95	68.0
26	24.0	61	39.6	96	69.1
27	24.4	62	40.2	97	70.2
28	24.7	63	40.9	98	71.3
29	25.1	64	41.5	99	72.4
30	25.5	65	42.2	100	73.5
31	25.9	66	42.9	101	74.6
32	26.3	67	43.6	102	75.7
33	26.7	68	44.3	103	76.8
34	27.1	69	45.0	104	77.95

Solubility of Ferrous Ammonium Sulphate.
(Tobler, 1855).

°C.	$FeSO_4 \cdot (NH_4)_2SO_4$ W.	°C.	$FeSO_4 \cdot (NH_4)_2SO_4$ W.
0	12.2	45	36.2
12	17.5	55	40.3
20	21.6	60	44.6
30	28.1	65	49.8
36	31.8	75	56.7

Solubility of Ferrous Sulphate. (Fraenkel, 1907).

°C.	$FeSO_4$ W.	S.	°C.	$FeSO_4$ W.	S.
0	15.65	13.53	55	53.15	34.70
5	18.07	15.32	*(i) 56.17	54.60	35.32
10	20.51	17.02	60	54.94	35.46
15	23.48	19.01	*(ii) 64.00	55.36	35.63
20	26.60	21.01	65	54.64	35.33
25	29.81	22.96	70	50.99	33.77
30	32.94	24.78	75	47.47	32.19
35	36.40	26.69	80	43.90	30.51
40	40.15	28.65	85	40.58	28.86
45	44.14	30.62	90	37.35	27.19
50	48.43	32.63			

*Transition points : (i) Hydrate with 7 aq.+4 aq.; (ii) Hydrate with 4 aq.+1 aq.

Solubility of Lead Chloride. (Lichty, 1903.)

°C.	Grams. $PbCl_2$ in 100 grams. water.	Grams. $PbCl_2$ in 100 cc. solution.	°C.	Grams. $PbCl_2$ in 100 grams. water.	Grams. $PbCl_2$ in 100 cc. solution.
0	0.6728	0.6728	55	1.8263	1.8019
15	0.9090	0.9070	65	2.1265	2.0810
25	1.0842	1.0786	80	2.6224	2.5420
35	1.3244	1.315	95	3.1654	3.0358
45	1.5673	1.5498	100	3.342	3.208

Solubility of Lead Nitrate. (Mulder).

°C.	$Pb(NO_3)_2$ W.	°C.	$Pb(NO_3)_2$ W.	°C.	$Pb(NO_3)_2$ W.
0	36.5	36	65.9	72	99.7
1	37.4	37	66.7	73	100.7
2	38.3	38	67.6	74	101.7
3	39.1	39	68.5	75	102.6
4	39.8	40	69.4	76	103.6
5	40.5	41	70.3	77	104.6
6	41.2	42	71.2	78	105.6
7	42.0	43	72.1	79	106.6
8	42.8	44	73.0	80	107.6
9	43.6	45	74.0	81	108.6
10	44.4	46	74.9	82	109.6
11	45.2	47	75.9	83	110.6
12	46.0	48	76.8	84	111.5
13	46.8	49	77.7	85	112.5
14	47.5	50	78.7	86	113.5
15	48.3	51	79.6	87	114.5
16	49.1	52	80.5	88	115.4
17	49.9	53	81.5	89	116.4
18	50.7	54	82.4	90	117.4
19	51.5	55	83.3	91	118.4
20	52.3	56	84.3	92	119.4
21	53.1	57	85.2	93	120.3
22	53.9	58	86.1	94	121.3
23	54.7	59	87.1	95	122.3
24	55.6	60	88.0	96	123.2
25	56.4	61	89.0	97	124.2
26	57.3	62	90.0	98	125.2
27	58.1	63	90.9	99	126.1
28	59.0	64	91.9	100	127.0
29	59.8	65	92.8	101	128.0
30	60.7	66	93.8	102	128.9
31	61.6	67	94.8	103	129.9
32	62.4	68	95.7	104	130.9
33	63.3	69	96.7	104.7	131.5
34	64.1	70	97.7		
35	65.0	71	98.7		

Solubility of Magnesium Sulphate.

°C.	MgSO$_4$. S.	W.	°C.	MgSO$_4$. S.	W.
0	21.0	26.6	50	33.5	50.4
*(i) 1.8	21.1	26.7	55	34.3	52.2
5	22.3	28.7	60	35.5	55.0
10	23.6	30.9	65	36.4	57.4
15	24.9	33.3	*(iii) 68	37.0	58.7
20	26.2	36.0	70	37.3	59.5
25	66.8	36.6	75	37.9	61.0
30	29.0	40.8	80	38.6	62.9
35	30.1	43.1	85	40.3	67.5
40	31.3	45.6	90	40.4	67.8
45	32.4	47.9	95	40.5	68.1
*(ii) 48	33.0	49.3	99.4	40.6	68.4

* Transition points: Hydrate with (i) 12 aq. + 7 aq. rhomb.: (ii) 7 aq. rhomb. + 6 aq.; (iii) 6 aq. + 1 aq.

Solubility of Manganese Sulphate.
(Cottrell, 1900).

°C.	MnSO$_4$. S.	W.	°C.	MnSO$_4$. S.	W.
0	34.7	53.16	50	37.3	59.48
5	36.0	56.28	55	36.6	57.81
*(i) 9	37.2	59.23	60	35.9	55.98
10	37.3	59.41	65	35.0	53.98
15	37.9	60.05	70	34.2	51.98
20	38.6	62.88	75	33.2	49.63
25	39.3	64.75	80	32.0	47.11
*(ii) 27	39.8	66.13	85	30.7	44.28
30	39.4	65.03	90	29.1	40.95
35	38.9	62.04	95	27.1	37.23
40	38.4	62.28	100	24.9	33.16
45	37.8	60.77			

*Transition points: (1) Hydrate with 7 aq. + 5 aq.; (ii) Hydrate with 5 aq. + 1 aq.

Solubility of Mercuric Chloride. (Poggiale).

°C.	$HgCl_2$ W.	°C.	$HgCl_2$ W.	°C.	$HgCl_2$ W.
0	5.73	40	9.62	80	24.30
10	6.57	50	11.34	90	37.05
20	7.39	60	13.86	100	53.96
30	8.43	70	17.29		

Solubility of Naphthionic Acid and ortho-Naphthionic Acid. (Dolinski, 1905).

°C.	p-Acid. W.	o-Acid. W.	°C.	p-Acid. W.	o-Acid. W.
0	0.027	0.24	60	0.075	1.01
10	0.029	0.32	70	0.097	1.37
20	0.031	0.41	80	0.130	1.80
30	0.037	0.52	90	0.175	2.40
40	0.048	0.65	100	0.228	3.19
50	0.059	0.81			

Solubility of Nickel Chloride. (Etard, 1894).

°C.	$NiCl_2$ S.	$NiCl_2$ W.	°C.	$NiCl_2$ S.	$NiCl_2$ W.
0	36.0	56.3	50	43.2	76.1
5	36.8	58.2	55	44.1	78.9
10	37.5	60.0	60	44.8	81.2
15	38.2	61.8	65	45.5	83.5
20	39.0	63.9	70	46.2	85.9
25	39.7	65 8	*75	46.5	86.9
30	40.5	68.1	80	46.5	86.9
35	41.1	69.8	85	46.6	87.3
40	41.9	72.1	90	46.7	87.6
45	42.6	74.2	95	46.8	88.0

* Transition point: Hydrate with 4 aq. + 2 aq. There is another at 36.2°, hydrate with 6 aq. + 4 aq.

Solubility of Nickel Ammonium Sulphate.
(Tobler 1855).

°C.	$NiSO_4.(NH_4)_2SO_4$ W.	°C.	$NiSO_4.(NH_4)_2SO_4$ W.
3.5	1.8	40	11.5
10	3.2	50	14.4
14	5.8	59	16.7
16	5.9	68	18.8
20	8.3	85	28.6

Solubility of Nickel Sulphate.
(Steele and Johnson, 1904).

°C.	$NiSO_4.$ W.	$NiSO_4.$ S.	°C.	$NiSO_4.$ W.	$NiSO_4.$ S.
0	27.22	21.40	*(ii) 53.3	52.67	34.50
5	29.52	22.75	55	53.24	34.74
10	31.84	24.12	60	54.84	35.45
15	34.19	25.50	65	58.15	36.64
20	36.91	26.93	70	59.44	37.30
25	39.67	28.35	75	61.18	37.96
30	42.47	29.80	80	63.17	38.70
*(i) 31.5	43.28	30.20	85	65.59	39.31
35	43.86	30.78	90	68.21	40.65
40	46.59	31.57	95	71.72	42.04
45	48.09	32.45	99	76.71	43.40
50	50.15	33.40			

* Transition points: (1) **Hydrate with 7 aq. + 6 aq.** (blue); (ii) **Hydrate with 6 aq.** (blue) + **6 aq.** (green).

Solubility of Oxalic Acid.
(Alluard 1869; Miczynski, 1886; Henry, 1884; Foote and Andrews, 1905).

°C.	Anhydrous acid. W.	S.	°C.	Anhydrous acid. W.	S.
0	3.45	3.33	40	21.15	17.46
10	5.55	5.26	50	31.53	23.97
20	8.78	8.07	60	45.55	31.37
25	11.36	10.21	70	63.82	38.95
30	13.77	11.91			

Solubilities of the Platinichlorides.

Platinichlorides.	Crookes.		Bunsen and Kirchhoff.	
	15°C. W.	100°C. W.	20°C. W.	100°C. W.
$(NH_4)_2PtCl_6$	0.67	1.25	–	–
K_2PtCl_6	0.926	5.26	1.12	5.18
Cs_2PtCl_6	0.076	0.383	0.079	0.377
Rb_2PtCl_6	0.135	0.637	0.141	0.634
Tl_2PtCl_6	0.0064	0.051	–	–

Solubility of Potash Alum. (Berkeley, 1904).

°C.	Anhydrous salt. W.	S.	°C.	Anhydrous salt. W.	S.
0	2.90	2.83	31	8.75	8.04
1	3.06	2.97	32	9.08	8.32
2	3.17	3.08	33	9.41	8.60
3	3.28	3.18	34	9.75	8.88
4	3.37	3.26	35	10.06	9.14
5	3.50	3.38	36	10.43	9.44
6	3.65	3.52	37	10.79	9.73
7	3.78	3.64	38	11.18	10.05
8	3.92	3.77	39	11.56	10.36
9	4.05	3.85	40	11.94	10.66
10	4.21	4.04	41	12.37	11.00
11	4.37	4.04	42	12.78	11.33
12	4.53	4.33	43	13.19	11.65
13	4.67	4.46	44	13.63	11.99
14	4.84	4.61	45	14.12	12.37
15	4.97	4.74	46	14.64	12.77
16	5.15	4.89	47	15.15	13.15
17	5.34	5.06	48	15.70	13.56
18	5.50	5.21	49	16.29	14.00
19	5.68	5.37	50	16.89	14.46
20	5.90	5.57	51	17.59	14.96
21	6.09	5.74	52	18.29	15.46
22	6.30	5.92	53	18.99	15.96
23	6.53	6.12	54	19.75	16.40
24	6.75	6.32	55	20.50	17.01
25	7.01	6.55	56	21.24	17.52
26	7.25	6.76	57	22.05	18.05
27	7.53	7.00	58	22.87	18.61
28	7.75	7.19	59	23.74	19.27
29	8.09	7.48	60	24.62	19.75
30	8.40	7.74			

Solubility of Potassium Acetate. (Osann).

	W.	
2°C.	188	CH_3COOK
13.9°C.	229	,,
62°C.	492	,,

Solubility of Potassium Antimonyl Tartrate (Tartar Emetic). (Brandes).

°C.	$2K(SbO)C_4H_4O_6+H_2O$ W.	°C.	$2K(SbO)C_4H_4O_6+H_2O$ W.
8.7	5.26	50	18.18
21	7.94	75	31.25
31	12.20	100	35.71

Solubility of Potassium Bitartrate. (Babo).

°C.	$KHC_4H_4O_6$ W.	°C.	$KHC_4H_4O_6$ W.
0	0.370	40	1.461
15	0.411	50	1.954
25	0.845	80	4.166
30	1.024	100	6.100

Solubility of Potassium Bromide. (Kremers).

°C.	KBr W.	°C.	KBr. W.
0	53.48	60	84.74
20	64.60	80	93.46
40	74.62	100	102.04

Solubility of Potassium Carbonate. (Mulder).

°C.	K_2CO_3 W.	°C.	K_2CO_3 W.	°C.	K_2CO_3 W.
0	89.4	46	119	92	149
1	94	47	120	93	150
2	97	48	120	94	151
3	100	49	121	95	151
4	102	50	121	96	152
5	104	51	122	97	153
6	105	52	122	98	154
7	106	53	123	99	155
8	107	54	124	100	156
9	108	55	124	101	157
10	109	56	125	102	158
11	109	57	125	103	159
12	109	58	126	104	160
13	110	59	127	105	161
14	110	60	127	106	162
15	110	61	128	107	163
16	111	62	128	108	164
17	111	63	129	109	166
18	111	64	130	110	167
19	111	65	130	111	168
20	112	66	131	112	169
21	112	67	132	113	171
22	112	68	132	114	172
23	112	69	133	115	173
24	112	70	133	116	175
25	113	71	134	117	176
26	113	72	135	118	178
27	113	73	135	119	179
28	113	74	136	120	181
29	114	75	137	121	182
30	114	76	137	122	184
31	114	77	138	123	185
32	114	78	139	124	187
33	115	79	139	125	188
34	115	80	140	126	190
35	115	81	141	127	191
36	115	82	141	128	193
37	116	83	142	129	195
38	116	84	143	130	196
39	116	85	144	131	198
40	117	86	144	132	200
41	117	87	145	133	201
42	117	88	146	134	203
43	118	89	147	135	205
44	118	90	147		
45	119	91	148		

Solubility of Potassium Chlorate and Potassium Perchlorate.

	(Gay Lussac.)	(Tilden and Shenstone 1880.)			(Muir.)
°C.	$KClO_3$ W.	°C.	$KClO_3$ W.	°C.	$KClO_4$ W.
0	3.33	0	3.3	0	0.71
13.32	5.60	100	56.5	25	1.96
15.37	6.03	120	73.7	50	5.34
24.43	8.44	136	98.9	100	18.7
35.02	12.05	160	148		
49.08	18.96	190	183		
74.98	35.40				
104.78	60.24				

Solubility of Potassium Chloride. (Berkeley, 1904).

°C.	KCl.		°C	KCl.	
	W.	S.		W.	S.
0	28.13	21.95	60	45.88	31.45
5	29.67	22.87	65	47.13	32.04
10	31.29	23.85	70	48.38	32.61
15	32.90	24.75	75	49.63	33.17
20	34.51	25.66	80	50.95	33.75
25	36.00	26.47	85	52.26	34.32
30	37.49	27.27	90	53.56	34.88
35	38.93	28.02	95	54.84	35.42
40	40.32	28.73	100	56.08	35.93
45	41.71	29.43	105	57.35	36.45
50	43.10	30.12	*108.0	58.11	36.75
55	44.49	30.79	* B.P. saturated solution.		

Simultaneous Solubility of Potassium Chloride—Sodium Chloride. (Precht and Wittjen, 1881).

A solution which is saturated with both salts contains W_1 gms. of KCl and W_2 gms. of NaCl to 100 gms. of water.

°C.	W_1	W_2	°C.	W_1	W_2
10	12.5	29.7	60	24.6	27.2
20	14.7	29.2	70	27.3	26.8
30	17.2	28.7	80	30.0	26.4
40	19.5	28.2	90	32.9	26.1
50	22.0	27.7	100	34.7	25.8

Solubility of Potassium Chloride in Magnesium Chloride Solutions
(Precht and Wittjen, 1881).

A solution of $MgCl_2$ and KCl, which when saturated with KCl at 10°C. contains 30, 21·2, etc., gms. $MgCl_2$ in 100 gms. of solution, contains, when saturated with KCl at the temperatures given, S gms. KCl in 100 gms. of solution.

°C.	30% $MgCl_2$ S.	21.2% $MgCl_2$ S.	15% $MgCl_2$ S.	11% $MgCl_2$ S.
10	1.9	5 3	9.9	14.3
20	2.6	6.5	11.3	15.9
30	3.4	7.6	12.7	17.5
40	4.2	8.8	14.2	19.0
50	5.0	10.0	15.6	20.5
60	5.8	11.2	17.0	21.9
70	6.5	12.4	18.3	23.2
80	7.3	13.6	19.5	24.5
90	8.1	14.7	20.8	25.8
100	8.9	15.9	22.1	27.1

Simultaneous Solubility of Potassium Chloride and Sodium Chloride in 20% Magnesium Chloride Solutions. (Precht and Wittjen, 1881).

A solution of $MgCl_2$, KCl and NaCl, which when saturated both with KCl and with NaCl at 10°C. contains 20 gms. $MgCl_2$ in 100 gms. of solution, contains when saturated with both salts at the temperatures given, S_1 gms. of KCl and S_2 gms. of NaCl in 100 gms. of solution.

°C.	% KCl S_1	% NaCl S_2	°C.	% KCl S_1	% NaCl S_2
10	4.2	5.7	60	8·9	6.3
20	5.1	5.8	70	9.9	6.4
30	6.0	5.9	80	10.9	6.6
40	6.9	6.0	90	11.9	6.7
50	7.9	6.1	100	13.0	6.9

Solubility of Potassium Chromate.

(Koppel and Blumenthal, 1907).

°C.	K_2CrO_4. W.	K_2CrO_4. S.	°C.	K_2CrO_4. W.	K_2CrO_4. S.
0	57.11	36.35	55	72.4	42.0
5	58.2	36.8	60	74.60	42.7
10	59.49	37.3	65	75.6	43.1
15	60.8	37.8	70	77.2	43.6
20	62.25	38.3	75	78.7	44.0
25	63.7	38.9	80	80.3	44.5
30	65.11	39.4	85	81.9	45.0
35	66.49	39.9	90	83.6	45.5
40	67.9	40.4	95	85.2	46.0
45	69.48	41.0	100	86.8	46.5
50	70.9	41.5	*105.8	88.8	47.0

* B.P. saturated solution.

Solubility of Potassium Dichromate.

(Koppel and Blumenthal, 1907).

°C.	$K_2Cr_2O_7$. W.	$K_2Cr_2O_7$. S.	°C.	$K_2Cr_2O_7$. W.	$K_2Cr_2O_7$. S.
0	4.64	4.43	55	37.99	27.53
5	5.89	5.56	60	45.44	31.24
10	7.66	7.11	65	47.10	32.02
15	9.60	8.76	70	53.68	34.93
20	12.12	10.81	75	59.91	37.42
25	14.83	12.91	80	66.41	39.91
30	18.13	15.35	85	73.43	42.34
35	21.70	17.83	90	81.31	44.85
40	25.41	20.26	95	89.85	47.33
45	29.33	22.68	100	98.90	49.72
50	33.43	25.05	*104.8	108.20	51.97

* B.P. saturated solution.

Solubility of Potassium Ferricyanide.
(Wallace, 1885).

°C.	$K_3Fe(CN)_6$ W.	°C.	$K_3Fe(CN)_6$ W.
4.4	33.0	37.8	58.8
10	36.6	100	77.5
15.6	40.8	104.4	82.6

Solubility of Potassium Ferrocyanide.
(Thomson, 1896).

	W.	
12.2 °C.	27.8	$K_4Fe(CN)_6$
37.7 °C.	65.8	,,
65.5 °C.	87.6	,,
96.3 °C.	90.6	,,

Solubility of Potassium Hydroxide.
(Pickering, 1893 : Ferchland, 1902).

°C.	KOH W.	KOH S.	°C.	KOH W.	KOH S.	°C.	KOH W.	KOH S.
-2.2*	3.7	3.6	-23.2	85	45.9	+32.5§	135	57.44
-20.7*	22.5	18.4	0	97	49.2	50	140	58.33
-65.2*	44.5	30.8	+10	103	50.7	100	178	64.03
-36.2†	36.2	26.6	15	107	51.7	125	213	68.06
-32.7†	77.94	43.8	20	112	52.8	143	311.7	75.73
-33‡	80	44.4	30	125	55.76			

Solid phases : * Ice; † $KOH.4H_2O$; ‡ $KOH.4H_2O + KOH.2H_2O$; § $KOH.2H_2O + KOH.H_2O$.

Solubility of Potassium Iodide. (Mulder).

°C.	KI. W.	°C.	KI. W.	°C.	KI. W.
0	127.9	40	160	80	192
1	128.7	41	161	81	193
2	129.6	42	162	82	194
3	130.4	43	163	83	195
4	131.2	44	164	84	196
5	132.1	45	164	85	197
6	132.9	46	165	86	197
7	133.7	47	166	87	198
8	134.5	48	167	88	199
9	135.3	49	168	89	200
10	136.1	50	168	90	201
11	137.0	51	169	91	202
12	137.8	52	170	92	202
13	138.6	53	171	93	203
14	139.4	54	172	94	204
15	140.2	55	172	95	205
16	141.0	56	173	96	206
17	141.8	57	174	97	207
18	142.6	58	175	98	208
19	143.4	59	175	99	208
20	144.2	60	176	100	209
21	145.1	61	177	101	210
22	145.9	62	178	102	211
23	146.7	63	179	103	212
24	147.5	64	180	104	213
25	148.3	65	180	105	213
26	149.1	66	181	106	214
27	149.9	67	182	107	215
28	150.7	68	183	108	216
29	151.5	69	184	109	217
30	152.3	70	184	110	218
31	153	71	185	111	219
32	154	72	186	112	220
33	155	73	187	113	220
34	156	74	188	114	221
35	156	75	188	115	222
36	157	76	189	116	223
37	158	77	190	117	223.6
38	159	78	191		
39	160	79	192		

Solubility of Potassium Nitrate.   (Berkeley, 1904).

| °C. | KNO$_3$ | | °C. | KNO$_3$ | |
	W.	S.		W.	S.
0	13.13	11.62	60	101.07	50.29
5	17.71	15.05	65	108.80	52.11
10	21.94	17.99	70	136.35	57.69
15	26.40	20.89	75	153.87	60.61
20	33.02	24.82	80	171.10	63.11
25	39.76	28.45	85	188.07	65.29
30	46.76	31.86	90	204.92	67.20
35	55.57	35.72	95	226.02	69.33
40	65.52	39.58	100	248.64	71.32
45	75.09	42.89	105	271.02	73.05
50	84.04	45.66	110	293.62	74.60
55	93.00	48.19	*114.0	311.64	75.71

* B.P. saturated solution.

Solubility of Mixtures of Potassium Nitrate and Sodium Nitrate at 20° C.
(Carnelly and Thomson, 1888).

% NaNO$_3$ before soln.	Grm. mixture in 100 grm. water.	Grm. NaNO$_3$ dissolved.	Grm. KNO$_3$ dissolved.	% NaNO$_3$ on evaporation.
100	86.8	86.8	0	100
90	109.6	96.4	13.2	88
80	136.5	98.0	38.5	71.8
70	136.3	–	–	–
60	137.6	90.0	47.6	65.4
50	106.1	66.0	40.1	62.2
45.7	88.0	53.3	34.7	60.6
40	81.1	45.6	35.6	56.2
30	73.5	–	–	–
20	54.1	20.8	33.3	38.5
10	40.9	9.4	31.5	22.9
0	33.6	0	33.6	0

Solubility of Potassium Sulphate.
(Berkeley, 1904).

°C.	K₂SO₄. W.	K₂SO₄. S.	°C.	K₂SO₄ W	K₂SO₄. S.
0	7.40	6.89	60	18.81	15.83
5	8.34	7.70	65	19.01	15.97
10	9.29	8.50	70	19.83	16.55
15	10.24	9.29	75	20.66	17.12
20	11.18	10.06	80	21.35	17.59
25	12.13	10.83	85	22.05	18.07
30	13.07	11.56	90	22.74	18.53
35	14.03	12.30	95	23.40	18.96
40	14.99	13.04	100	24.06	19.39
45	15.85	13.68	*101.1	24.21	19.49
50	16.63	14.26			
55	17.41	14.83			

* B.P. of saturated solution.

Solubility of Potassium Thiocyanate.
(Rudorff, 1869).

	W.	
0°C.	177.2	KCNS
20°C.	217	,,

Solubility of Potassium Iodate. (Kremers, 1858).

°C.	KIO₃. W.	°C.	KIO₃. W.
0	4.73	60	18.5
20	8.13	80	24.8
40	12.8	100	32.2

Solubility of Acid Potassium Oxalate. (Alluard).

°C.	KHC₂O₄ W.	°C.	KHC₂O₄ W.
0	2.2	60	20.5
10	3.1	80	34.7
20	5.2	100	51.5
40	10.5		

Solubility of Salicylic Acid.
(See Solubility of Benzoic Acid).

Solubility of Silver Chloride in Salt Solutions.
(Hahn, 1877)

The figures under % Salt are gms. salt in 100 gms. solution.
Vogel (and others) give sometimes very different values for
solubility of AgCl.

Salt.	% Salt.	Saturated at °C.	% AgCl
KCl	24.95	19.6	0.0776
NaCl	25.96	19.6	0.1053
NH$_4$Cl	28.45	24.5	0.3397
CaCl$_2$	41.26	24.5	0.5713
MgCl$_2$	36.35	24.5	0.5313
BaCl$_2$	27.32	24.5	0.0570
FeCl$_2$	30.70	–	0.1686
FeCl$_3$	37.48	–	0.0058
MnCl$_2$	43.85	24.5	0.1996
ZnCl$_2$	53.34	–	0.0134
CuCl$_2$	44.48	24.5	0.0532
PbCl$_2$	0.99	24.5	0.0000

Solubility of Silver Nitrate.
(From mean values Landolt Börnstein's tables, 1905).

°C.	AgNO$_3$ W.	S.	°C.	AgNO$_3$ W.	S.
0	115	53	70	550	85
10	160	61	80	650	87
20	215	68	90	760	88
30	270	73	100	910	90
40	335	77	110	1110	92
50	400	80	125	1941	95
60	470	82			

Solubility of Sodium Acetate.   (Osann).

	W.	
6°C.	25.7	CH$_3$COONa+3H$_2$O
37°C.	41.7	,,
48°C.	58.8	,,

Solubility of Sodium Bicarbonate.
(Fedotieff, 1904).

°C.	NaHCO$_3$.		°C.	NaHCO$_3$.	
	W.	S.		W.	S.
0	6.90	6.45	25	10.24	9.29
5	7.51	6.98	30	11.02	9.93
10	8.15	7.54	35	11.86	10.60
15	8.80	8.09	40	12.82	11.36
20	9.51	8.70	45	13.86	12.17

Note.—In these determinations p CO_2 + p H_2O = 1 atmosphere.

Solubility of Sodium Bromate, Sodium Chlorate and Sodium Iodate. (Kremers, 1855).

°C.	NaBrO$_3$ W.	NaClO$_3$ W.	NaIO$_3$ W.	°C.	NaBrO$_3$ W.	NaClO$_3$ W.	NaIO$_3$ W.
0	27.54	81.9	2.52	80	75.75	175.6	27.70
20	34.48	99	9.07	100	90.90	204.1	33.90
40	50.25	123.5	14.39	120	–	333.3	–
60	62.50	147.1	20.88				

Solubility of Sodium Bromide. (De Coppet, 1883)

°C.	NaBr.		°C.	NaBr.	
	S	W.		S.	W.
– 20	41.8	71.8	*50.7	53.9	116.9
10	42.9	75.1	60	53.9	116.9
0	44.3	79.5	70	54.0	117.4
+10	45.7	84.2	80	54.2	118.3
20	47.5	90.5	90	54.5	119.8
30	49.3	97.2	100	54.8	121.2
40	51.4	105.8	110	55.1	122.7
50	53.7	116.0	121 B.P.	–	–

* Transition point : Hydrate with 2 aq. + NaBr.

Solubility of Sodium Carbonate (Mulder).

°C.	Na_2CO_3 W.	°C.	Na_2CO_3 W.
0	7.0	*32.5	46.2
5	9.5	35	46.2
10	12.5	40	46.1
15	16.4	60	46.0
20	21.5	80	45.8
25	28.2	100	45.5
30	37.8	105	45.2

* Transition point : Hydrate with 10 aq.+ 1 aq.

Solubilities of Sodium Carbonate and Sodium Bicarbonate in Sodium Chloride Solutions at 15°C. (Reich).

% NaCl	Grms. Na_2CO_3 in 100 grms. NaCl soln.	% NaCl	Grms. Na_2CO_3 in 100 grms. NaCl soln.
0	16.41	12	10.49
1	15.72	13	10.24
2	15.06	14	10.04
3	14.44	15	9.88
4	13.85	16	9.76
5	13.30	17	9.69
6	12.78	18	9.65
7	12.31	19	9.67
8	11.86	20	9.72
9	11.46	21	9.83
10	10.10	22	10.00
11	10.77		

After precipitating bicarbonate by carbon dioxide :

% NaCl	Grms. $NaHCO_3$ in 100 grms. NaCl soln.
10.64	3.00
15.80	1.87
21.82	1.06

Solubility of Sodium Chloride. (Berkeley, 1904).

°C.	NaCl. W.	NaCl. S.	°C.	NaCl. W.	NaCl. S.
0	35.70	26.31	60	37.28	27.16
5	35.78	26.35	65	37.47	27.26
10	35.82	26.37	70	37.64	27.35
15	35.85	26.39	75	37.81	27.44
20	35.97	26.45	80	38.05	27.56
25	36.09	26.52	85	38.31	27.70
30	36.20	26.58	90	38.57	27.83
35	36.34	26.65	95	38.90	28.01
40	36.48	26.73	100	39.24	28.18
45	36.60	26.79	105	39.34	28.23
50	36.83	26.92	*107.0	39.65	28.39
55	36.96	26.99			

* B.P. saturated solution.

Solubility of Sodium Chromate.
(Mylius and Funk, 1900).

°C.	Na_2CrO_4 W.	°C.	Na_2CrO_4 W.	°C.	Na_2CrO_4 W.
0	31.7	40	96	68	123.5
10	50.2	50	105	80	124
21	89.9	60	115	100	126

Solubility of Sodium Dichromate.
(Mylius and Funk, 1900).

°C.	$Na_2Cr_2O_7$ W.	°C.	$Na_2Cr_2O_7$ W.	°C.	$Na_2Cr_2O_7$ W.
0	163	40	220	80	386
10	170	50	248	93	432
20	180	60	283	98	433
30	197	70	323		

Solubility of Sodium Ferrocyanide
(Conroy, 1898).

	W.	
20° C.	17.9	$Na_4Fe(CN)_6$
42° C.	30.2	,,
80° C.	59.2	,,
98.5° C.	63.0	,,

Solubility of Sodium Hydroxide.
(Pickering, 1893; Mylius and Funk, 1900).

°C.	NaOH. W.	NaOH. S.	°C.	NaOH. W.	NaOH. S.	°C.	NaOH. W.	NaOH. S.
− 7.8	8.7	8.0	+10	51.5	34.0	50	145	59.2
− 20	19.1	16.0	15.5	63.5	38.9	60	174	63.5
− 28*	23.5	19.0	5†	83.5	45.5	64.3	222.3	69.0
− 24	28.5	22.2	12§	103	50.7	61.8**	288	74.2
− 17.7	32.5	24.5	20	109	52.2	80	313	75.8
0	42.0	29.6	30	119	54.3	110	365	78.5
+ 5	47.5	32.2	40	129	56.3	192	521	83.9

Solid phases at transition points :   * ice + 2NaOH.7H₂O;
† 2NaOH.7H₂O + NaOH.2H₂O;   § NaOH.2H₂O + NaOH.H₂O;
** NaOH.H₂O + NaOH.

Solubility of Sodium Iodide.   (De Coppet, 1883).

°C.	NaI. S.	NaI. W.	°C.	NaI. S.	NaI. W.
0	61.4	151.9	60	72.0	257.1
10	62.8	168.8	*65	74.4	290.6
20	64.2	179.3	70	74.5	292.2
30	65.5	189.8	80	74.7	295.3
40	67.2	204.9	90	74.9	298.4
50	69.5	220.6	100	75.1	301.6

* Transition point : Hydrate with 2 aq. + NaI.

Solubility of Sodium Nitrate. (Berkeley, 1904)

°C.	NaNO$_3$. W.	S.	°C.	NaNO$_3$. W	S.
0	73.07	42.22	65	130.30	56.58
5	76.77	43.43	70	135.98	57.62
10	80.45	44.58	75	141.72	58.63
15	84.16	45.70	80	148.12	59.70
20	88.11	46.84	85	154.66	60.73
25	92.13	47.95	90	161.27	61.72
30	96.15	49.02	95	169.42	62.88
35	100.60	50.15	100	177.66	63.98
40	105.16	51.26	105	185.77	65.01
45	109.58	52.29	110	194.06	65.99
50	115.09	53.51	115	202.28	66.92
55	119.82	54.51	*119.0	208.84	67.62
60	124.56	55.47			

* B.P. saturated solution.

Solubility of Sodium Phosphate.
(Dans and Schreiner, Shiomi, 1910).

°C.	Na$_2$HPO$_4$. W.	S.	°C.	Na$_2$HPO$_4$. W.	S.
0	2.51	2.45	*(ii) 48.35	79.00	44.13
5	2.90	2.82	50	80.16	44.50
10	3.50	3.38	55	85.44	46.07
15	5.16	4.90	60	91.41	47.76
20	7.80	7.40	65	93.39	48.29
25	12.47	11.08	70	94.99	48.72
30	20.64	17.11	75	95.81	48.93
35	43.96	30.54	80	96.63	49.14
*(i) 35.4	46.11	31.56	85	97.27	49.31
40	54.34	35.21	90	97.81	49.45
45	69.04	40.84	91	98.15	49.54

* Transition points : (i) Hydrate with 12 aq. and 7 aq.; (ii) Hydrate with 7 aq. and 2 aq.

Solubility of Sodium Sulphate. (Berkeley, 1904).

°C.	Na₂SO₄ W.	S.	°C.	Na₂SO₄ W.	S.
0	4.67	4.46	55	45.96	31.49
5	6.73	6.31	60	45.24	31.15
10	9.08	8.32	56	44.65	30.87
15	13.54	11.92	70	44.10	30.60
20	20.41	16.95	75	43.60	30.36
25	27.89	21.81	80	43.28	30.21
30	40.95	29.05	85	42.97	30.06
*32.5	49.70	33.20	90	42.66	29.90
35	49.09	32.93	95	42.46	29.80
40	48.20	32.51	100	42.26	29.72
45	47.41	32.16	†101.9	42.18	29.67
50	46.72	31.84			

* Transition point : Hydrate with 10 aq. + Na₂SO₄.
† B.P. saturated solution.

(Richards and Yngve, 1918).

Note.—Exact determinations, using Na₂SO₄ 10 H₂O, for temperature measurements between 15° and 25°C. to 0.01°.

°C.	Na₂SO₄ W.	°C.	Na₂SO₄ W.
15.000	13.181	21	20.549
16	14.185	22	22.155
17	15.268	23	23.888
18	16.437	24	25.762
19	17.698	25	27.795
20	19.064		

Solubility of Sodium Sulphite.
(Hartley and Barrett, 1909).

°C.	Na₂SO₃ W.	S.	°C.	Na₂SO₃ W.	S.
-1.9	13.09	11.57	25	28.5	22.18
0	13.90	12.20	30	28.5	22.18
+5	16.32	14.03	37	28.04	21.90
10	19.25	16.14	47	28.13	21.95
15	22.95	18.67	55	28.21	22.00
20	26.67	21.05	84	28.25	22.03
*22	28.6	22.24			

* Transition point : Hydrate with 7 aq. + Na₂SO₃.

III. LIQUIDS IN LIQUIDS.

If two liquids A and B which are not miscible in all proportions are in contact with one another, the layer containing an excess of A will contain a certain proportion of B and *vice-versâ*. The solubilities vary with the temperature, rapidly near the critical solution temperature above which A and B are miscible in all proportions : some pairs of liquids show a lower critical point and are completely miscible below, partially above this temperature.

The solubilities are given as gms. of first-mentioned substance in 100 gms of mixture. Critical solution temperatures are marked with an asterisk : in many cases they are above the boiling-point of the mixture.

	°C.	20	40	60	100	140	167*
Aniline in water	%	3.1	3.3	3.8	7.2	13.5	48.6
Water in aniline	%	5.0	5.3	5.8	8.4	16.9	51.4

	°C.	15	29	58	95	112	187.5*
iso-Amyl alcohol in water	%	2.7	2.3	2.2	2.7	3.4	36.6

	°C.	15.5	—	69.5	97.3	122.3	187.5
Water in iso-amyl alcohol	%	9.3	—	12.6	16.0	19.8	63.4

	°C.	0	10.3	20	30.2	40	49.9
Bromine in water	%	4.00	3.60	3.40	3.32	3.33	3.40

	°C.	0	10	20	30	40	49
Carbon bisulphide in water	%	.20	.19	.18	.15	.11	.01

	°C.	10	20	25	30	35	40.5*
Carbon bisulphide in methyl alcohol	%	44.9	50.4	53.8	57.9	63.9	80.5
Methyl alcohol in CS_2	%	1.8	2.6	3.2	4.4	6.7	19.5

	°C.	-4	0	10	20	30	40
Ether in water	%	12.6	12.2	9.0	6.5	5.0	4.5
Water in ether	%	.94	.93	1.09	1.22	1.35	1.6

	°C.	-20	0	20	40	80	150*
Methyl-ethyl ketone in water	%	40.1	30.6	22.6	18.6	15.7	45
Water in Me-Et-ketone	%	10.6	10.6	10.4	9.9	10.4	14.2	55

	°C.	20	30	55	—	—	—
Nitrobenzene in water	%	.19	.22	.27	—	—	—

	°C.	8.8	14.7	30.8	44.2	63.3	106.6
Water in nitrobenzene	%	.174	.194	.299	.401	.713	1.53

	°C.	—	38	—	58.8	65.2	65.3*
Phenol in water	%	—	9.5	—	16.2	34.2	36.5

	°C.	20.6	—	42.7	—	60.2	65.3
Water in phenol	%	28.6	—	35.3	—	46.1	63.5

	°C.	3	23	40	55	66	77
Water in benzene	%	.03	.06	.11	.18	.26	.33

	°C.	18	53	79	94	—	—
Water in paraffin oil S_{20}^{20} .792, b.p. 190°—250°C.	%	.005	.026	.063	.097	—	—

Correction of Gas Volumes.

The tables below give the factor by which the volume of a gas measured at the stated pressure p mms. of mercury (corrected for temperature and gravity according to the barometric tables later), and at the stated temperature $t°$C. must be multiplied to find the volume at $0°$C., and 760 mms. of mercury at $0°$C. and lat. $45°$ at sea-level. A decimal point is to be inserted before the first figure. If the gas is measured when containing aqueous vapour in amount corresponding with a pressure of e mm., the factor found opposite the pressure $p-e$ must be used to find the volume of the dry gas at N.T.P. Values of e for saturated vapour are given in the table "Vapour Pressure of Water."

Conversely, if the density D_0 at N.T.P. be known, the density at a pressure p and temperature t is found by multiplying by the factor in the table. If the density required be that of the moist gas in which the pressure of water vapour is e, this is equal to

$$D_0 \times \frac{1}{1+at} \times \frac{p-e}{760} + w_0 \frac{1}{1+at} \times \frac{e}{769}, \text{ where } w_0 = 0.8044.$$

The value of the coefficient of expansion assumed in calculating the table is 0.0036690, which is more nearly an average for ordinary "permanent" gases than the usual $1/273$. The actual values of a for different gases are given in the second column of table of "Coefficients of Expansion of Gases," and for the most accurate work the requisite correction to be subtracted from the factor is calculated at 760 mm. pressure for every five degrees. Corrections greater than $.00100$ are not likely to be accurate to more than $.0001$, except for CO_2, owing to inaccuracy in a.

Allowance may be made for the departure of the gas from Boyle's Law by the use of the coefficients A in the third column of the table. The coefficient A is the variation of pv per cm. of mercury pressure difference from 76 cms., expressed as a fraction of pv at N.T.P. The magnitude of the correction at 71 cms. pressure is given for various temperatures in the table, the correction for a differences being included.

Use of the difference columns in the main table. The differences per $1°$C. in the last column of each page may be

used for interpolating to tenths of a degree : the multiplication is carried out in the small table at the foot of each page. It should be noted (i) that the differences are to be *subtracted* for increasing temperature, and (ii) that they are correct only for the interval between the third and fourth columns of temperatures : for the second to third or four to fifth columns they are 2 units too low or too high respectively, and for the first to second or fifth to next page they are 4 units too low or too high respectively throughout.

The differences per mm. and for each tenth of a mm. are given in the top line of the multiplication table, and are to be *added*.

Example. To reduce to N.T.P. from 9·3°C. and 730·8 mm. The figure found for 9°C. and 730 mm. is 92982 : the corresponding difference per 1°C. is 334 − 4 = 330 : hence difference for ·3°C. = 99. The difference per mm. is 128, hence for ·8 mm. it is 102. Required factor is 92982 − 99 + 102 = 92985, with decimal point to be inserted before the first figure. The result should be accurate to ± ·00001.

An alternative method of reducing to N.T.P. the volumes of readily liquefied gases, which does not require an accurate knowledge of the compressibility or of the coefficient of expansion over the range considered, is founded on Berthelot's equation of state

$$PV = \frac{273 \cdot 1 + t}{273 \cdot 1} \left\{ 1 - (a_t - b) \; \frac{1}{V} \right\} \text{ where } a_t = a_o \times \left(\frac{273 \cdot 1}{273 \cdot 1 + t} \right)^2$$

and the values of a_o and b are calculated from the critical constants of the gas θ_c^0 absolute and P_c by the relations

$$a_o = \frac{27}{64} \left(\frac{\theta_c}{273 \cdot 1} \right) \frac{1}{P_c} \text{ and } b = \frac{9}{128} \times \frac{1}{273 \cdot 1} \frac{\theta_c}{P_c}$$

This leads to a value of the correction factor for reducing to N.T.P.

$$\text{factor} = \frac{P}{760} \times \frac{273 \cdot 1}{273 \cdot 1 + t} \times \frac{1}{1 + a_c \left\{ 1 - f \left(\frac{273 \cdot 1}{273 \cdot 1 + t} \right)^2 \right\} - b(1 - f)}$$

in which expression f is the approximate factor read off in the table. The correction given by this expression may be used for such gases as SO_2, of which the a is not known with accuracy, but the critical constants are available.

COEFFICIENTS OF EXPANSION AND OF COMPRESSIBILITY OF GASES IN NEIGHBOURHOOD OF ROOM CONDITIONS.

Gas.	$a \times 10^5$	$A \times 10^5$	p mm.	Correction $\times 10^5$ to be subtracted from f at				
				7·5°C.	12·5°C.	17·5°C.	22·5°C.	27·5°C.
Air	366·9 Rg. "C."	0·75 Ra.'	760	0	0	0	0	0
			710	3	3	3	3	
N_2	367·3 C.'	0·68Ra.C.	760	3	5	6	7	
			710	6	7	9	10	11
H_2	366·1 R.M.	− 0·71 Ra J.S.	760	−6	−9	−12	−15	−18
			710	−2	−5	− 8	−11	−14
CO	366·5 Rg."	1·07 Ra.	760	−3	−5	− 6	− 7	− 9
			710	2	0	− 1	− 2	− 4
CO_2	373·7 to 373·4 C.'	8·77 Ra.	760	48	77	103	127	147
	373·2 to 372·9		710	82	106	127	146	164
N_2O	372·9 Rg."	9·83 Ra.	760	43	69	92	115	134
			710	85	108	129	149	168
CN	388 Rg.	25·5 L.	760	150	240	320	400	470
			710	260	330	310	490	550
SO_2	398 L.	31·4 J.S.	760	220	360	480	600	700
			710	350	470	580	680	780
C_2H_2	374 L.	9·3 L.	760	50	80	108	135	158
			710	88	116	141	164	186
NH_3	386 P.'	20·1 J.S.	760	135	219	294	366	430
			710	217	292	362	425	486
NO	368 L.'	1·54 J.S.	760	7	11	15	19	22
			710	76	79	82	84	86
HCl	374 L.'	9·83 B.	760	50	80	108	135	158
			710	91	119	144	167	189
C_2H_4	374 L.	8·2 L.	760	50	80	108	135	158
			710	83	111	137	160	182
O_2	368 L.'	0·94 Ra.	760	7	11	15	19	22
			710	11	15	18	22	25
H_2S	377 L '	10·7 L.	760	71	115	154	192	225
			710	114	154	190	224	255
Cl	383 L.	—	760	113	184	247	308	362
C_2H_6	377 L.	—	760	71	115	154	192	225
CH_4	368	—	760	7	11	15	19	22

Rg. Regnault, Ra. Rayleigh, C. Chappius, R. M. Richards and Marks, J. S. Jacquerod and Scheuer, B. Burt, L. Leduc (calc.), P. Perman, C' interpolated from C., C" calculated from C, by analogy of critical data, from values for 0—100°C.

Table for Correction to N.T.P.

	5°.	6°.	7°.	8°.	9°.	Diff.
701	90575	90250	89927	89607	89288	321
2	704	379	90056	735	416	321
3	834	508	184	862	543	321
4	963	636	312	990	671	322
5	91092	765	440	90118	798	322
6	221	894	569	246	925	323
7	350	91023	697	374	90053	323
8	480	151	825	501	180	324
9	609	280	954	629	307	324
710	738	409	91082	757	435	325
1	867	538	210	885	562	325
2	997	666	338	91013	690	326
3	92126	795	467	141	817	326
4	255	924	595	268	944	326
5	384	92052	723	396	91072	327
6	513	181	852	524	199	327
7	643	310	980	652	326	328
8	772	439	92108	780	454	328
9	901	567	236	908	581	329
720	93030	696	365	92035	709	329
1	159	825	493	163	836	330
2	289	954	621	291	963	330
3	418	93082	749	419	92091	331
4	547	211	878	547	218	331
5	676	340	93006	675	345	331
6	805	469	134	802	473	332
7	935	597	263	930	600	332
8	94064	726	391	93058	728	333
9	193	855	519	186	855	333
730	322	984	647	314	982	334
1	451	94112	776	442	93110	334
2	581	241	904	569	237	335
3	710	370	94032	697	364	335
4	839	499	161	825	492	336
5	968	627	289	953	619	336

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
128	13	26	38	51	64	77	90	102	115
322	32	64	97	129	161	193	225	258	290
325	32	65	97	130	162	195	227	260	292
328	33	66	98	131	164	197	230	262	295
331	33	66	99	132	165	199	232	265	298
334	33	67	100	134	167	200	234	267	301
337	34	67	101	135	168	202	236	270	303

F

	5°.	6°.	7°.	8°.	9°.	Diff.
736	95098	94756	94417	94081	93747	337
7	227	885	545	208	874	337
8	356	95014	674	336	94001	337
9	485	142	802	464	129	338
740	614	271	930	592	256	338
1	744	400	95059	720	383	339
2	873	529	187	848	511	339
3	96002	657	315	975	638	340
4	131	786	443	95103	766	340
5	260	915	572	231	893	341
6	390	96044	700	359	95020	341
7	519	172	828	487	148	342
8	648	301	957	615	275	342
9	777	430	96085	742	402	342
750	906	559	213	870	530	343
1	97036	687	341	998	657	343
2	165	816	470	96126	784	344
3	294	945	598	254	912	344
4	423	97074	726	382	96039	345
5	553	202	855	509	167	345
6	682	331	983	637	294	346
7	811	460	97111	765	421	346
8	940	589	239	893	549	347
9	98069	717	368	97021	676	347
760	199	846	496	148	803	348
1	328	975	624	276	931	348
2	457	98103	753	404	97058	348
3	586	232	881	532	186	349
4	715	361	98009	660	315	349
5	845	490	137	788	440	350
6	974	618	266	915	568	350
7	99103	747	394	98043	695	351
8	232	876	522	171	822	351
9	361	99005	651	299	950	352
770	491	133	779	427	98077	352

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
128	13	26	38	51	64	77	90	102	115
340	34	68	102	136	170	204	238	272	306
343	34	69	103	137	171	206	240	274	309
346	35	69	104	138	173	208	242	277	311
349	35	70	105	140	174	209	244	279	314
352	35	70	106	141	176	211	246	282	317
355	35	71	106	142	177	213	248	284	319

	10°.	11°.	12°.	13°.	14°.	Diff.
701	88972	88659	88347	88038	87730	309
2	89099	785	473	163	856	310
3	226	912	599	289	981	310
4	353	89038	725	414	88106	311
5	480	165	851	540	231	311
6	607	291	977	666	356	312
7	734	418	89103	791	481	312
8	861	544	229	917	607	312
9	988	670	355	89042	732	313
710	90115	797	481	168	857	313
1	242	923	607	294	982	314
2	369	90050	733	419	89107	314
3	495	176	859	545	232	315
4	622	303	985	670	357	315
5	749	429	90112	796	483	316
6	876	556	238	922	608	316
7	91003	682	364	90047	733	316
8	130	809	490	173	858	317
9	257	935	616	298	983	317
720	384	91062	742	424	90108	318
1	511	188	868	549	233	318
2	638	315	994	675	359	319
3	765	441	91120	801	484	319
4	892	568	246	926	609	320
5	92019	694	372	91052	734	320
6	145	821	498	177	859	320
7	272	947	524	303	984	321
8	399	92073	750	429	91110	321
9	526	200	876	554	235	322
730	653	326	92002	680	360	322
1	780	453	128	805	485	323
2	907	579	254	931	610	323
3	93034	706	380	92057	735	323
4	161	832	506	182	860	324
5	288	959	632	308	986	324

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
126	13	25	38	50	63	76	88	101	113
310	31	62	93	124	155	186	217	248	279
313	31	63	94	125	156	188	219	250	282
316	32	63	95	126	158	190	221	253	284
319	32	64	96	128	159	191	223	255	287
322	32	64	97	129	161	193	225	258	290
325	32	65	97	130	162	195	227	260	292

	10°.	11°.	12°.	13°.	14°.	Diff.
736	93415	93085	92758	92433	92111	325
7	542	212	884	559	236	325
8	669	338	93010	684	361	326
9	795	465	136	810	486	326
740	922	591	262	936	611	327
1	94049	718	388	93061	736	327
2	176	844	514	187	862	327
3	303	971	640	312	987	328
4	430	94099	766	438	93112	328
5	557	224	892	564	237	329
6	684	350	94018	689	362	329
7	811	476	144	815	487	330
8	938	603	271	940	613	330
9	95065	729	397	94066	738	331
750	192	856	523	192	863	331
1	319	982	649	317	988	331
2	445	95109	775	443	94113	332
3	572	235	901	568	238	332
4	699	362	95027	694	363	333
5	826	488	153	820	489	333
6	953	615	279	945	614	334
7	96080	741	405	95071	739	334
8	207	868	531	196	864	335
9	334	994	657	322	989	335
760	461	96121	783	447	95114	335
1	588	247	909	573	240	336
2	715	374	96035	699	365	336
3	842	500	161	824	490	337
4	969	627	287	950	615	337
5	97095	753	413	96075	740	338
6	222	880	539	201	865	338
7	349	97006	665	327	990	339
8	476	132	791	452	96116	339
9	603	259	917	578	241	339
770	730	385	97043	703	366	340

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
126	13	25	38	50	63	76	88	101	113
328	33	66	98	131	164	197	230	262	295
331	33	66	99	132	165	199	232	265	298
334	33	67	100	134	167	200	234	267	301
337	34	67	101	135	168	202	236	270	303
340	34	68	102	136	170	204	238	272	306
343	34	69	103	137	171	206	240	274	309

	15°.	16°.	17°.	18°.	19°.	Diff.
701	87425	87122	86822	86523	86226	299
2	550	247	945	646	349	299
3	675	371	87069	770	472	300
4	800	495	193	893	595	300
5	924	620	317	87016	718	301
6	88049	744	441	140	841	301
7	174	868	565	263	964	301
8	298	992	688	387	87087	302
9	423	88117	812	510	210	302
710	548	241	936	634	333	303
1	673	365	88060	757	456	303
2	797	490	184	880	579	304
3	922	614	308	88004	702	304
4	89047	738	432	127	825	304
5	171	862	555	251	948	305
6	296	987	679	374	88071	305
7	421	89111	803	498	194	306
8	546	235	927	621	317	306
9	670	360	89051	744	440	306
720	795	484	175	868	563	307
1	920	608	299	991	686	307
2	90044	732	422	89115	809	308
3	169	857	546	238	932	308
4	294	981	670	362	89055	309
5	419	90105	794	485	178	309
6	543	229	918	608	301	309
7	668	354	— 90042	732	424	310
8	793	478	166	855	547	310
9	917	602	289	979	670	311
730	91042	727	413	90102	793	311
1	167	851	537	226	916	312
2	292	975	661	349	90039	312
3	416	91099	785	472	162	312
4	541	224	909	596	285	313
5	666	348	91033	719	408	313

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
124	12	25	37	50	62	74	87	99	112
298	30	60	89	119	149	179	209	238	268
301	30	60	90	120	150	181	211	241	271
304	30	61	91	122	152	182	213	243	274
307	31	61	92	123	153	184	215	246	276
310	31	62	93	124	155	186	217	248	279
313	31	63	94	125	156	188	219	250	282

	15°.	16°.	17°.	18°.	19°.	Diff.
736	91790	91472	91156	90843	90531	314
7	915	597	280	966	654	314
8	92040	721	404	91090	777	315
9	165	845	528	213	900	315
740	289	969	652	336	91023	315
1	414	92094	776	460	146	316
2	539	218	900	583	269	316
3	663	342	)2023	707	392	317
4	788	467	147	830	515	317
5	913	591	271	954	638	318
6	93038	715	395	92077	761	318
7	162	839	519	200	884	318
8	287	964	643	324	92007	319
9	412	93088	767	447	130	319
750	536	212	890	571	253	320
1	661	337	93014	694	376	320
2	786	461	138	818	499	321
3	911	585	262	941	622	321
4	94035	709	386	93064	745	321
5	160	834	510	188	868	322
6	285	958	633	311	991	322
7	409	94082	757	435	93114	323
8	534	207	881	558	237	323
9	659	331	94005	682	360	324
760	784	455	129	805	483	324
1	908	579	253	928	606	324
2	95033	704	377	94052	729	325
3	158	828	500	175	852	325
4	282	952	624	299	975	326
5	407	95077	748	422	94098	326
6	532	201	872	546	221	327
7	657	325	996	669	344	327
8	781	449	95120	792	467	327
9	906	574	244	916	590	328
770	96031	698	367	95039	713	328

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
124	12	25	37	50	62	74	87	99	112
316	32	63	95	126	158	190	221	253	284
319	32	64	96	128	159	191	223	255	287
322	32	64	97	129	161	193	225	258	290
325	32	65	97	130	162	195	227	260	292
328	33	66	98	131	164	197	230	262	295
331	33	66	99	132	165	199	232	265	298

	20°.	21°.	22°.	23°.	24°.	Diff.
701	85931	85639	85348	85059	84772	289
2	86054	761	469	180	893	289
3	176	883	591	302	85014	290
4	299	86005	713	423	135	290
5	422	127	835	544	256	290
6	544	249	956	666	377	291
7	667	372	86078	787	498	291
8	789	494	200	908	619	292
9	912	616	322	86030	740	292
710	87034	738	443	151	860	292
1	157	860	565	272	981	293
2	280	982	687	394	86102	283
3	402	87105	809	515	223	294
4	525	227	931	636	344	294
5	647	349	87052	758	465	295
6	770	471	174	879	586	295
7	892	593	296	87000	707	295
8	88015	715	418	122	828	296
9	138	838	539	243	949	296
720	260	960	661	364	87070	297
1	383	88082	783	486	191	297
2	505	204	905	607	312	297
3	628	326	88026	728	433	298
4	751	448	148	850	554	298
5	873	571	270	971	674	299
6	996	693	392	88092	795	299
7	89118	815	513	214	916	299
8	241	937	635	335	88037	300
9	364	89059	757	456	158	300
730	486	181	879	578	279	301
1	609	304	89000	699	400	301
2	731	426	122	820	521	302
3	854	548	244	942	642	302
4	976	670	366	89063	763	302
5	90099	792	487	184	884	303

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
122	12	24	37	49	61	73	85	98	110
286	29	57	86	114	143	172	200	229	257
289	29	58	87	116	144	173	202	231	260
292	29	58	88	117	146	175	204	234	263
295	29	59	88	118	147	177	206	236	265
298	30	60	89	119	149	179	209	238	268
301	30	60	90	120	150	181	211	241	271

	20°.	21°.	22°.	23°.	24°.	Diff.
736	90222	89914	89609	89306	89005	303
7	344	90036	731	427	126	304
8	467	159	853	548	247	304
9	589	281	974	670	367	304
740	712	403	90096	791	488	305
1	835	525	218	913	609	305
2	957	647	340	90034	730	306
3	91080	769	461	155	851	306
4	202	892	583	277	972	306
5	325	91014	705	398	90093	307
6	447	136	827	519	214	307
7	570	258	948	641	335	308
8	693	380	91070	762	456	308
9	815	502	192	883	577	309
750	938	625	314	91005	698	309
1	92060	747	435	126	819	309
2	183	869	557	247	940	310
3	306	991	679	369	91061	310
4	428	92113	801	490	181	311
5	551	235	922	611	302	311
6	673	358	92044	733	423	311
7	796	480	166	854	544	312
8	918	602	288	975	665	312
9	93041	723	409	92097	786	313
760	164	846	531	218	907	313
1	286	968	653	339	92028	313
2	409	93091	775	461	149	314
3	531	213	896	582	270	314
4	654	335	93018	703	391	315
5	777	457	140	825	512	315
6	899	579	262	946	633	316
7	94022	701	383	93067	754	316
8	144	824	505	189	874	316
9	267	946	627	310	995	317
770	389	94068	749	431	93116	317

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
122	12	24	37	49	61	73	85	98	110
304	30	61	91	122	152	182	213	243	274
307	31	61	92	123	153	184	215	246	276
310	31	62	93	124	155	186	217	248	279
313	31	63	94	125	156	188	219	250	282
316	32	63	95	126	158	190	221	253	284
319	32	64	96	128	159	191	223	255	287

	25°.	26°.	27°.	28°.	29°.	Diff.
701	84487	84204	83923	83644	83367	279
2	608	324	84043	763	485	280
3	728	445	163	883	604	280
4	849	565	282	84002	723	280
5	969	685	402	121	842	281
6	85090	805	522	241	961	281
7	210	925	641	360	84080	282
8	331	85045	761	479	199	282
9	451	165	881	598	318	282
710	572	285	85001	718	437	283
1	692	405	120	837	556	283
2	813	526	240	956	675	284
3	934	646	360	85076	794	284
4	86054	766	480	195	913	284
5	175	886	599	314	85031	285
6	295	86006	719	434	150	285
7	416	126	839	553	269	286
8	536	246	958	672	388	286
9	657	366	86078	792	507	286
720	777	487	198	911	626	287
1	898	607	318	86030	745	287
2	87018	727	437	150	864	288
3	139	847	557	269	983	288
4	259	967	677	388	86102	288
5	380	87087	796	508	221	289
6	500	207	916	627	340	289
7	621	327	87036	746	459	290
8	741	447	156	866	578	290
9	862	568	275	985	696	290
730	982	688	395	87104	815	291
1	88103	808	515	224	934	291
2	223	928	634	343	87053	292
3	344	88048	754	462	172	292
4	465	168	874	582	291	292
5	585	288	994	701	410	293

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
120	12	24	36	48	60	72	84	96	108
274	27	55	82	110	137	164	192	219	247
277	28	55	83	111	138	166	194	222	249
280	28	56	84	112	140	168	196	224	252
293	28	57	85	113	141	170	198	226	255
286	29	57	86	114	143	172	200	229	257
289	29	58	87	116	144	173	202	231	260

	25°.	26°.	27°.	28°.	29°.	Diff.
736	88706	88408	88113	87820	87529	293
7	826	529	233	939	648	294
8	947	649	353	88059	767	294
9	89067	769	472	178	886	294
740	188	889	592	297	88005	295
1	308	89009	712	417	124	295
2	429	129	832	536	242	296
3	549	249	951	655	361	296
4	670	369	89071	775	480	296
5	790	490	191	894	599	297
6	911	610	311	89013	718	297
7	90031	730	430	133	837	298
8	152	850	550	252	956	298
9	272	970	670	371	89075	298
750	393	90090	789	491	194	299
1	513	210	909	610	313	299
2	634	330	90028	729	432	300
3	754	450	149	849	551	300
4	875	571	268	968	670	300
5	996	691	388	90087	788	301
6	91116	811	508	207	907	301
7	237	931	627	326	90026	302
8	357	91051	747	445	145	302
9	478	171	867	565	264	302
760	598	291	987	684	383	303
1	719	411	91106	803	502	303
2	839	532	226	923	621	304
3	960	652	346	91042	740	304
4	92080	772	465	161	859	304
5	201	892	585	280	978	305
6	321	92012	705	400	91097	305
7	442	132	825	519	216	306
8	562	252	944	638	335	306
9	683	372	92064	758	453	306
770	803	493	184	877	572	307

Diff.	·1.	·2.	·3.	·4.	·5.	·6.	·7.	·8.	·9.
120	12	24	36	48	60	72	84	96	108
292	29	58	88	117	146	175	204	234	263
295	29	59	88	118	147	177	206	236	265
298	30	60	89	119	149	179	209	238	268
301	30	60	90	120	150	181	211	241	271
304	30	61	91	122	152	182	213	243	274
307	31	61	92	123	153	184	215	246	276

Correction of Barometer Readings.

The reading of the barometer requires to be corrected (i) for capillary depression of the mercury if the tube is less than about 15 mm. in bore, (ii) for temperature of the mercury column and scale, (iii) for variation of " gravity " from the standard owing to difference in latitude from 45° or to height above sea-level. Corrections (ii) and (iii) are necessary, since standard gravity, to which condition densities of gases are always reduced for comparison, signifies that at lat. 45° and sea-level, the mercury column being at 0°C.

REDUCTION OF BAROMETRIC READINGS TO 0°C.

The corrected height $B_o = B_t \left\{ 1 - \dfrac{(\beta - a)t}{1 + \beta t} \right\}$ where B_t is the reading observed at the temperature $t°$C., corrected if necessary for capillary depression of the mercury, β is the coefficient of cubical expansion of mercury, and a the coefficient of linear expansion of the scale. The table below gives values of the correction $B_t \times \dfrac{(\beta - a)t}{1 + \beta t}$ to be subtracted from B_t for barometers with a brass scale, assuming $\beta = 1818 \times 10^{-7}$ and $a = 184 \times 10^{-7}$ (*International Meteorological Tables*, 1890). For barometers with glass scales, for which $a = 85 \times 10^{-7}$, the correction is greater by 6·1% than the value given for brass scales. B_t and the correction are in mm.

				Uncorrected	height.					
$t°$C.	700.	710.	720.	730.	740.	750.	760.	770.	780.	790.
1	.11	.12	.12	.12	.12	.12	.12	.13	.13	.13
2	.23	.23	.24	.24	.24	.25	.25	.25	.25	.26
3	.34	.35	.35	.36	.36	.37	.37	.38	.38	.39
4	.46	.46	.47	.48	.48	.49	.50	.50	.51	.52
5	.57	.58	.59	.60	.60	.61	.62	.63	.64	.64
6	.69	.70	.71	.71	.72	.73	.74	.75	.76	.77
7	.80	.81	.82	.83	.85	.86	.87	.88	.89	.90
8	.91	.93	.94	.95	.97	.98	.99	1.01	1.02	1.03
9	1.03	1.04	1.06	1.07	1.09	1.10	1.12	1.13	1.15	1.16
10	1.14	1.16	1.17	1.19	1.21	1.22	1.24	1.26	1.27	1.29
11	1.26	1.27	1.29	1.31	1.33	1.35	1.36	1.38	1.40	1.42
12	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.53	1.55
13	1.48	1.50	1.53	1.55	1.57	1.59	1.61	1.63	1.65	1.67
14	1.60	1.62	1.64	1.67	1.69	1.71	1.73	1.76	1.78	1.80
15	1.71	1.74	1.76	1.78	1.81	1.83	1.86	1.88	1.91	1.93

$t°C.$	700.	710.	720.	730.	Uncorrected height. 740.	750.	760.	770.	780.	790.
16	1.82	1.85	1.88	1.90	1.93	1.96	1.98	2.01	2.03	2.06
17	1.94	1.97	1.99	2.02	2.05	2.08	2.10	2.13	2.16	2.19
18	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	2.29	2.32
19	2.17	2.20	2.23	2.26	2.29	2.32	2.35	2.38	2.41	2.44
20	2.28	2.31	2.34	2.38	2.41	2.44	2.47	2.51	2.54	2.57
21	2.39	2.43	2.46	2.50	2.53	2.56	2.60	2.63	2.67	2.70
22	2.51	2.54	2.58	2.61	2.65	2.69	2.72	2.76	2.79	2.83
23	2.62	2.66	2.69	2.73	2.77	2.81	2.84	2.88	2.92	2.96
24	2.73	2.77	2.81	2.85	2.89	2.93	2.97	3.01	3.05	3.08
25	2.85	2.89	2.93	2.97	3.01	3.05	3.09	3.13	3.17	3.21
26	2.96	3.00	3.04	3.09	3.13	3.17	3.21	3.26	3.30	3.34
27	3.07	3.12	3.16	3.20	3.25	3.29	3.34	3.38	3.42	3.47
28	3.19	3.23	3.28	3.32	3.37	3.41	3.46	3.51	3.55	3.60
29	3.30	3.35	3.39	3.44	3.49	3.54	3.58	3.63	3.68	3.72
30	3.41	3.46	3.51	3.56	3.61	3.66	3.71	3.75	3.80	3.85

REDUCTION OF BAROMETRIC READINGS TO LAT. 45° AND SEA-LEVEL.

The standard value of gravity is that at lat. 45° and sea-level. The corrections given below in mm. are to be subtracted from B_o for latitudes 0°—45°, and added for latitudes 45° to 90°. The correction for height above sea-level is to be subtracted from B_o after it has been reduced to lat. 45°.

B_o	Latitude. 25° 65°.	30°. 60°.	35°. 55°.	40°. 50°.	Height above sea-level, metres. 200.	400.	600.	800.	1000.
680	1.13	0.88	0.60	0.31	0.03	0.05	0.08	0.11	0.13
700	1.17	0.91	0.62	0.31	0.03	0.05	0.08	0.11	0.14
720	1.20	0.93	0.64	0.32	0.03	0.06	0.08	0.11	0.14
740	1.23	0.96	0.66	0.33	0.03	0.06	0.09	0.12	—
760	1.27	0.98	0.67	0.34	0.03	0.06	—	—	—
780	1.30	1.01	0.69	0.35	0.03	—	—	—	—

The approximate latitudes of London and Cardiff are 51.5° (0.45), Birmingham and Aberystwyth 52.5° (0.50), Manchester and Sheffield 53.5° (0.57), Newcastle 55°, Glasgow 56° (0.74), the latitude corrections for which are, for $B_o = 760$, the figures given in brackets.

CAPILLARY DEPRESSION OF MERCURY IN A GLASS TUBE.

(Mendeleeff and Gutkowski; Kohlrausch.)

The depressions given are in mms. and are to be added to the observed reading of the barometer if the lower reservoir has a diameter of 25 mms. or more. The correction varies with the cleanliness of the mercury and glass.

Diam.	Height of meniscus in mm.							
mm.	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
4	0.83	1.22	1.54	1.93	2.37	—	—	—
5	0.47	0.65	0.86	1.19	1.45	1.80	—	—
6	0.27	0.41	0.56	0.78	0.98	1.21	1.43	—
7	0.17	0.28	0.40	0.53	0.67	0.82	0.97	1.13
8	—	0.20	0.29	0.33	0.46	0.56	0.65	0.77
9	—	0.15	0.21	0.28	0.33	0.40	0.46	0.52
10	—	—	0.15	0.20	0.25	0.29	0.33	0.37
11	—	—	0.10	0.14	0.18	0.21	0.24	0.27
12	—	—	0.07	0.10	0.13	0.15	0.18	0.19
13	—	—	0.04	0.07	0.10	0.12	0.13	0.14

Vapour Pressures.

Saturation pressure of water vapour below 0°C., in mm. of mercury at 0°C. and lat. 45° (Scheel and Heuse, *Ann. d. Phys.*, 1909, **29**, 723).

°C.	Over ice.	Over water.	°C.	Over ice.	Over water.	°C.	Over ice.
0	4.579	4.579	−10	1.963	2.160	−20	0.784
−1	4.219	4.259	−11	1.797	1.996	−25	0.480
−2	3.885	3.958	−12	1.644	1.843	−30	0.288
−3	3.575	3.678	−13	1.503	1.701	−35	0.168
−4	3.288	3.415	−14	1.373	1.568	−40	0.096
−5	3.022	3.171	−15	1.253	1.445	−45	0.053
−6	2.776	2.942	−16	1.143	1.331	−50	0.030
−7	2.548	2.727	−17	1.041		−55	0.016
−8	2.337	2.525	−18	0.948		−60	0.007
−9	2.143	2.337	−19	0.863		−65	0.002

Saturation Vapour Pressure of Water.

In mm. of Mercury at 0°C and lat. 45°.

°C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	4.579	4.613	4.647	4.681	4.715	4.750	4.785	4.820	4.855	4.890
1	4.926	4.962	4.998	5.034	5.071	5.107	5.144	5.181	5.219	5.256
2	5.294	5.332	5.370	5.409	5.447	5.487	5.526	5.565	5.605	5.645
3	5.685	5.726	5.766	5.807	5.848	5.890	5.932	5.974	6.016	6.058
4	6.101	6.144	6.187	6.231	6.274	6.319	6.363	6.407	6.452	6.497
5	6.543	6.589	6.635	6.681	6.728	6.775	6.822	6.870	6.918	6.966
6	7.014	7.063	7.111	7.161	7.210	7.260	7.310	7.361	7.411	7.463
7	7.514	7.566	7.618	7.670	7.723	7.776	7.830	7.883	7.937	7.991
8	8.046	8.101	8.156	8.211	8.267	8.324	8.380	8.437	8.494	8.552
9	8.610	8.669	8.727	8.787	8.846	8.905	8.966	9.027	9.087	9.148
10	9.210	9.272	9.334	9.396	9.459	9.523	9.586	9.650	9.715	9.780
11	9.845	9.911	9.977	10.043	10.110	10.177	10.245	10.313	10.381	10.450
12	10.519	10.589	10.659	10.729	10.800	10.871	10.942	11.015	11.087	11.160
13	11.233	11.307	11.381	11.455	11.530	11.606	11.681	11.758	11.834	11.911
14	11.989	12.067	12.146	12.225	12.304	12.384	12.464	12.545	12.626	12.708
15	12.790	12.873	12.956	13.039	13.123	13.208	13.292	13.378	13.464	13.550
16	13.637	13.724	13.812	13.901	13.989	14.079	14.169	14.259	14.350	14.441
17	14.533	14.625	14.718	14.812	14.906	15.000	15.095	15.190	15.286	15.383
18	15.480	15.578	15.676	15.774	15.874	15.974	16.074	16.175	16.276	16.378
19	16.481	16.584	16.688	16.792	16.897	17.003	17.109	17.216	17.323	17.431
20	17.539	17.648	17.758	17.868	17.978	18.090	18.202	18.314	18.427	18.541
21	18.655	18.770	18.885	19.001	19.118	19.236	19.354	19.472	19.592	19.711
22	19.832	19.953	20.075	20.198	20.321	20.445	20.569	20.695	20.820	20.947
23	21.074	21.202	21.330	21.459	21.589	21.720	21.851	21.983	22.116	22.249
24	22.383	22.518	22.653	22.789	22.926	23.064	23.202	23.341	23.481	23.622
25	23.763	23.905	24.048	24.192	24.336	24.481	24.627	24.773	24.920	25.068
26	25.217	25.366	25.517	25.668	25.819	25.972	26.125	26.280	26.435	26.590
27	26.747	26.905	27.063	27.222	27.382	27.542	27.704	27.866	28.029	28.193
28	28.358	28.523	28.690	28.857	29.025	29.195	29.364	29.535	29.706	29.879
29	30.052	30.226	30.401	30.578	30.754	30.932	31.111	31.290	31.471	31.652
30	31.834	32.017	32.201	32.386	32.572	32.759	32.946	33.134	33.324	33.514
31	33.706	33.898	34.092	34.286	34.482	34.678	34.875	35.073	35.273	35.473
32	35.674	35.876	36.079	36.284	36.489	36.695	36.902	37.110	37.320	37.530
33	37.741	37.953	38.167	38.381	38.597	38.813	39.030	39.249	39.469	39.689
34	39.911	40.134	40.358	40.583	40.809	41.036	41.264	41.493	41.724	41.955
35	42.188	42.422	42.657	42.893	43.130	43.368	43.608	43.848	44.090	44.333

°C	0	1	2	3	4	5	6	7	8	9
30							44.58	47.08	49.71	52.46
40	55.34	58.36	61.52	64.82	68.28	71.90	75.67	79.62	83.74	88.05
50	92.54	97.21	102.10	107.20	112.51	118.06	123.82	129.84	136.09	142.61
60	149.38	156.43	163.77	171.39	179.31	187.54	196.09	204.96	214.18	223.74
70	233.7	244.0	254.6	265.7	277.2	289.0	301.4	314.1	327.3	341.0
80	355.1	369.7	384.9	400.5	416.7	433.5	450.8	468.6	487.1	506.1
90	525.8	546.1	567.1	588.7	611.0	634.0	657.7	682.1	707.3	733.3
100	760.0	787.5	815.9	845.1	875.1	906.1	937.9	970.6	1004.3	1038.8
110	1074.5	1111.1	1148.7	1187.4	1227.1	1267.9	1309.8	1352.8	1397.0	1442.4

°C	Atmos.	°C	Atmos.	°C	Atmos.
105	1.192	170	7.81	270	54.19
110	1.414	175	8.80	280	63.17
115	1.668	180	9.88	290	73.27
120	1.959	185	11.07	300	84.60
125	2.290	190	12.37	310	97.2
130	2.665	195	13.79	320	111.2
135	3.088	200	15.33	330	126.7
140	3.565	210	18.80	340	143.8
145	4.099	220	22.86	350	162.7
150	4.695	230	27.57	360	183.5
155	5.358	240	32.98	370	206.5
160	6.095	250	39.17	374*	218
165	6.910	260	46.22	*Critical	

The values from 0°C. to 50°C. are those given by Scheel and Heuse, *Ann. d. Phys.*, 1910, **31**, 715: the figures for each 0·1°C. from 0° to 35°C. have been interpolated from their results. From 51°C. to 80°C. the values are those calculated from Thiesen's formula (mean of all earlier deter-

minations), which requires 92·52 mm. at 50°C. instead of 92·54. From 80°C. to 200°C. Holborn and Henning's observations are tabulated, *Ann. d. Phys.*, 1908, **26**, 833, and above 200°C. those of Holborn and Baumann, *Ann. d. Phys.*, 1910, **31**, 968. 1 atmo. = 1·03326 kgs./cm² = 14·6974 lbs./in.²

Vapour Pressures of Various Substances.

Interpolation. To find the vapour pressure at a temperature between any two given in the tables, interpolate logarithms of vapour pressures instead of the pressures themselves, since log. p is approximately a linear function of t over short ranges.

More accurately, plot $\dfrac{\theta_x}{\theta_w}$ against θ_x where θ_w is the absolute temperature at which the vapour pressure of water is equal to that of the substance at θ_x absolute, using as many values of θ_x as are given. Draw a straight line through these points and read off the value of $\dfrac{\theta_x}{\theta_w}$ for the required temperature θ'_x : the temperature θ'_w given by this value of the ratio corresponds with a certain pressure p given in the tables for water : this pressure is also that exerted by the given substance at θ'_x. If the points lie well on the straight line extrapolation is permissible except near the critical temperature and pressure.

Similarly to find the temperature at which the given substance shall exert a pressure p_1, plot $\dfrac{\theta_x}{\theta_w}$ against θ_w and find the value of the ratio for the temperature θ''_w at which water has the pressure p_1. The temperature θ''_x given by the value of $\dfrac{\theta_x}{\theta_w}$ so found is that at which the substance also exerts the vapour pressure p_1.

Vapour Pressures of Liquefied Gases.

θ = °Absolute. p = mm. of mercury. P = atmospheres. t = °C.

Hydrogen — Cath and Onnes 1918

θ	14.20	16.94	19.03	20.39	20.62	27.29	32.93
p	61.8	232.5	502.3	760.0	810.9	3763	9364

Oxygen — Siemens 1913

θ	76.98	82.01	86.24	90.10
p	150	300	500	760

$$\log p = -\frac{399}{\theta} + 1.75\,\log\theta + 5.0527$$

Nitrogen — Siemens 1913

θ	64.55	66.93	70.22	73.10	76.55	77.25
p	120	180	300	450	700	760

$$\log p = -\frac{345.6}{\theta} + 1.75\,\log\theta + 4.7306$$

Acetylene — Villard 1895

t	−85 (solid)	−70	−50	−23.8	0.0	15	36.9
P	1.00	2.22	5.3	13.2	26.05	37.9	68.0

Ammonia — Brill,* Davies† 1906

t	−80*	−64.4*	−50†	−40†	−33.5†	−20†	−10†
p	35.2	116	293	557	760	1393	2146

Ammonia — Keyes 1918

t	0	10	20	30	40	100	132.9
P	4.28	6.13	8.53	11.60	15.44	61.75	112.3

$$\log_{10} p = \frac{1969.65}{\theta} + 16.19785 - 0.0423858\,\theta + 5.4131\times10^{-5}\,\theta^2 - 3.2716\times10^{-8}\,\theta^3$$

Carbon dioxide — Siemens 1913

t	−114.5	−106.8	−97.2	−89.2	−79.5	−78.44
p	20	50	170	300	700	760

$$\log p = -\frac{1378.3}{\theta} + 1.75\,\log\theta + 6.9484$$

Kuenen and Amagat

t	−50	−30	−10	0.0	+10	20	30
P	6.60	14.0	26.0	34.35	44.4	56.4	70.7

Chlorine — Pellaton 1915

t	−70	−34.5	−20	3.64	40	60	144
P	.147	1.00			11.14	17.5	76.10

Hydrochloric acid — Cardoso 1913

t	−44.4		0.0	6.57	+10	20	51.4
P	12.62	19.29	25.42	32.99	41.65	52.10	81.55

Nitrous oxide — Cailletet, Villard 1897

t	−92	−60	−34	0.0	13.2	20	
P	1.00	5.05	13.2	30.8	41.2	49.4	

Sulphur dioxide — Pictet

t	−30	−20	−10	0.0	+10	20	30
P	.36	.61	1.00	1.51	2.35	3.30	4.60

Sulphuretted hydrogen — Regnault

t	−20	−10	0.0	+10	20	30	40
P	5.8	8.0	10.8	14.3	18.6	23.7	29.7

Vapour Pressures of Various Liquids and Solids.

t = °C, p = mm. of mercury at 0°C.

Substance (reference)	row	values
Acetic acid (Ramsay and Young)	t	0, 20, 40, 60, 80, 100, 118.5
	p	3.4, 11.8, 34.5, 88.6, 202.3, 417, 760
Acetone (Regnault, Price 1918)	t	20, 30, 40, 50, 60, 56.2
	p	183.0, 282.3, 420.8, 615.3, 860, 760
iso-Amyl alcohol (Schmidt 1891)	t	20, 40, 60, 80, 100, 120, 136.85
	p	2.3, 9.3, 33.3, 95.2, 238.6, 523, 760
Aniline (Kahlbaum 1898)	t	43.1, 87.2, 119.4, 138.7, 161.1, 175.0, 183.9
	p	1, 10, 40, 100, 200, 400, 760
Benzene (Young 1889)	t	10, 30, 50, 70, 80.3, 90
	p	45.3, 118.0, 268.6, 547.8, 760, 1016
Bromine (Ramsay and Young 1886)	t	−16.6, −14.8, +8.2, +10, 23.4, 40.5, 58.7
	p	50, 100, 200, 400, 600, 760
Carbon disulphide (Siemens 1913)	t	−10, 0, 10, 20, 30, 46.25
	p	78.4, 127.0, 198.1, 298.3, 435.6, 760
Chloroform (Regnault)	t	0, 20, 40, 50, 60, 60.16
	p	60, 160, 369, 535, 755, 760
Ether (Young 1910)	t	−10, 0, 10, 20, 34.6, 40
	p	112.3, 184.9, 290.8, 439.8, 760, 921
Ethyl acetate (Wade 1912)	t	0, 10, 30, 60, 80, 77.15
	p	24.1, 42.9, 118.7, 415.1, 833.2, 760
Ethyl alcohol (Ramsay and Young 1886)	t	−10, 0, 20, 40, 60, 70, 78.3
	p	6.5, 12.7, 44.0, 133.4, 350.2, 541, 760
Iodine (Baxter 1915, Stelzner 1905)	t	60, 90, 116.5, 150, 184.4
	p	4.29, 26.8, 90, 309, 760
Mercury (Laby 1908)	t	20, 50, 100, 150, 200, 300, 356.7
	p	.0011, .0122, .28, .47, 17.8, 248.6, 760
Nitrobenzene (Kahlbaum 1898)	t	53.1, 103.9, 139.9, 160.5, 184.5, 199.5, 208.3
	p	1, 10, 40, 100, 200, 400, 760
Octane (Young 1900)	t	0, 20, 40, 60, 80, 100, 125.7
	p	2.9, 10.4, 30.8, 77.5, 160.0, 354, 760
Phenol (Kahlbaum 1898)	t	90.2, 120.2, 139.0, 160.0, 173.0, 181.4
	p	100, 200, 354, 514, 600, 760
Phosphorus (yellow) (Schrotter 1848)	t	131.9, 180, 204, 230, 266, 287.3
	p	44.8, 40, 100, 200, 400, 760
Sulphur (Ruff 1908, Matthies 1906, Bodenstein 1899)	t	165, 211.3, 306.5, 359, 393, 444.6
	p	.00034, .081, 3.14, 53.5, 240, 760

Total Vapour Pressure of Sulphuric Acid Water Mixtures .

In mm. of Mercury at o°C.

(Burt, *J.C.S.*, 1904, 1339.)

°C.	gms. H₂SO₄ in 100 gms. mixture.								
	24.92.	30.46.	35.54.	41.01.	48.37.	54.24.	62.81.	70.78.	74.36.
60	120.7	111.0	100.1	84.2	59.8	44.1			
70	192.7	176.6	159.5	136.5	100.4	74.0	35.4		
80	295.1	271.3	245.0	211.8	157.8	118.1	58.0		
90	439.1	403.4	366.0	317.2	241.2	182.9	92.3	35.5	
100	640.8	589.9	537.7	465.8	355.6	267.4	140.0	57.0	
110		762.7	757.2	670.2	515.4	391.9	210.8	89.0	
120		(107.1°)	(109.6°)		754.0	561.8	308.0	140.4	80.8
130					(120.8°)	753.7	438.3	205.2	120.4
140						(128.7°)	612.8	291.2	178.4
150								426.9	260.7
160								589.0	

°C.	% H₂SO₄.				
	77.26.	78.50.	81.15.	85.14.	86.61.
110	35.1				
120	56.1	47.7			
130	85.5	71.8	—		
140	127.7	108.0	65.3	31.5	
150	188.9	163.7	101.7	51.3	37.7
160	273.9	235.2	150.4	77.6	57.7
170	387.1	329.8	218.9	115.0	87.3
180	525.7	445.8		164.2	126.6
190	748.3	597.2		227.9	150.4
200	(189.9°)	756.3		307.4	(185°)
210		(198.3°)		424.6	
				(225°) 670·3	

°C.	% H₂SO₄.		
	88.4.	91.01.	95.94.
160	38.0		
170	59.4		
180	87.3	45.5	
190	120.5	67.9	(205°)
200	171.5	98.1	34.1
210	205.3	138.2	40.8
220	(205°)	190.3	60.8
230		263.5	85.9
235			106.0

Except at the highest concentrations and temperatures (say above 90% acid and 180°C.) the partial pressure of sulphuric acid is negligible, and the total pressures given represent the partial pressure of aqueous vapour. Partial pressures of water for lower temperatures than are recorded by Burt are given in Sorel's table below, and may also be obtained from the relative humidity table which follows it, which has been calculated from Regnault's data.

Partial Pressure of Aqueous Vapour above Diluted Sulphuric Acid.

In mm. of Mercury.

SOREL, 1889.

°C.	gms. H_2SO_4 in 100 gms. of mixture of acid and water.									
	44	48	52	56	60	64	68	72	76	80
10	4.4	3.7	3.0	2.2	1.6	1.2	0.9	0.7	0.4	0.2
30	15.5	13.4	10.9	8.1	6.1	4.0	3.0	2.0	1.4	0.8
50	48.3	40.1	31.5	24.1	16.9	10.9	7.2	4.8	3.0	1.9
70		107.2	84.5	65.0	46.1	30.3	19.4	12.0	7.5	4.1
90			207.9	160.0	118.7	83.7	56.0	33.7	18.5	9.3

Air of Constant Humidity.

Regnault's table shows that the equilibrium pressure of aqueous vapour above dilute sulphuric acid, expressed as % of the maximum pressure above pure water at the same temperature is as follows :—

	gms. H_2SO_4 in 100 gms. mixture.								
	84.48	73.13	64.47	57.65	52.13	43.75	37.69	33.10	24.26
	mols. H_2O per mol. H_2SO_4.								
°C.	1	2	3	4	5	7	9	11	17
10	1.25	5.46	13.09	20.57	33.05	48.73	63.03	70.05	84.15
20	0.89	4.90	12.89	21.44	33.30	48.84	62.28	70.82	83.27
30	0.71	4.72	12.87	22.23	33.87	49.44	62.11	70.22	82.78

This table has been calculated for the purpose of testing hygrometers, drying substances to constant, but not " dry " weight, etc.

The relative humidity of the air in equilibrium with a saturated solution of common salt is $80.15 \pm .05\%$ between 10°C. and 30°C.

Above caustic potash solutions, the relative humidity is as follows (after Wüllner) :—

°C.	gms. KOH in 100 gms. water.				
	10	20	30	40	49
10	94.0	87.4	79.8	71.0	61.3
20	94.2	87.7	80.1	71.3	61.8
30	94.2	88.0	80.5	71.9	62.5

Correction of Thermometer Readings.

The scientific standard thermometric scale is the thermo-dynamic or absolute scale : that of the constant-volume hydrogen thermometer agrees with this to within $0\cdot01°$ C. between $-100°$ C. and $+300°$ C. and is the International Standard in practical use since 1887.

Mercury thermometers with N.P.L. certificates have corrections to reduce their readings to the constant-volume H scale. Those with class A or "precision" test certificate are tested, unless the contrary is expressly stated, immersed up to the point being read and in a vertical position, no account being taken of zero change. Those with class B or "Kew" certificate are tested totally immersed, and with thermometer vertical. Readings are always taken with a rising mercury meniscus.

The following fixed points may be used to reproduce the hydrogen scale from $-200°$ C to $1100°$ C.

oxygen b.p. $-182°.9_5 + 0°.01258\ (p-760) - 0°.0000079\ (p-760)^2$
CO_2 b.p. $-78°.5 + 0°.01595\ (p-760) - 0.0000111\ (p-760)^2$
mercury f.p. -38.88 ice m.p. $0°$
$Na_2SO_4 10H_2O$ transition point to Na_2SO_4 anhydrous $32°.38_4$
water b.p. $100°.0$ at 760 mm. (see Broch's table below for pressure corrections).
naphthalene b.p. $217°.9_6 + 0°.058\ (p-760)$ tin f.p. $231°.8_4$
benzophenone b.p. $305°.9 + 0°.063\ (p-760)$
cadmium f.p. $320°.9$ zinc f.p. $419°.4$
sulphur b.p. $444°.5_4 + 0.0904\ (p-760) - 0.000052\ (p-760)^2$
antimony f.p. $630°$ common salt f.p. $801°$
silver f.p. $961°$ in reducing atmosphere   gold f.p $1063°$
copper f.p. $1083°$ in reducing atmosphere.

These fixed points are used both by the N.P.L. and by the Reichsanstalt. For the m.pts. of palladium and platinum the accepted values are $1549°$ and $1755°$ (Day and Sosman, 1911).

For fixing the hydrogen scale between $0°$ and $100°$ C. when standard thermometers are not available, Richards (1918) has suggested the following transition-points of carefully purified hydrated crystalline salts, in addition to sodium sulphate :—

$Na_2CrO_4 10H_2O \rightarrow Na_2CrO_4 6H_2O$ + solution $19°.525$ C
$Na_2CrO_4 10H_2O \rightarrow Na_2CrO_4 4H_2O$ + solution $19°.987$ C
$Na_2CO_3 10H_2O \rightarrow Na_2CO_3 7H_2O$ + solution $32°.017$ C.
$NaBr 2H_2O \rightarrow NaBr$ + solution $50°.674$ C.
$MnCl_2 4H_2O \rightarrow MnCl_2 2H_2O$ + solution $58°.089$ C.
$SrCl_2 6H_2O \rightarrow SrCl_2 2H_2O$ + solution $61°.341$ C.
$SrBr_2 6H_2O \rightarrow SrBr_2 2H_2O$ + solution $88°.62$ C.

Also benzene m.p. $5°.483$ C

For calibrating Beckmann freezing-point thermometers to be used for milk, etc., Schoorl suggests (1915)

KNO_3—ice eutectic (12.2% KNO_3) m.p. $-2°.86$ C.
$Ba(NO_3)_2$—ice eutectic (4.5% $Ba(NO_3)_2$) m.p. $-0°.71$ C.

Direct comparison with standard instruments is more accurate than calibration between a few fixed points, and is recommended by the N.P.L. in preference to the calibration method for mercury thermometers.

Mercury thermometers should be used, whenever possible, under the conditions specified for their corrections. They should not be exposed to high temperatures longer than necessary, since this produces permanent rise of zero, sometimes masked by distillation of the mercury to the top of the stem. For work of any accuracy above 200° C., gas-filled capillaries are necessary to minimise distillation. High-range thermometers should have a few graduations near the ice-point, and be checked frequently by observations of zero. When used *in vacuo,* thermometers may read 0°.1 C. or so too low.

If an emergent column is unavoidable, the following table may be used to reduce the error due to this cause if the thermometer has been standardised with thread immersed.

Correction of Thermometer Readings for Emergent-stem.

If t be the indicated temperature, t_a the temperature of the air indicated by a second thermometer whose bulb is 10 cms. to the side of the middle of the exposed thread and is shielded from the source of heat, and n the number of degree divisions of the thread not immersed in the hot liquid or vapour, the correction which must be added to t is, according to Kopp, $\delta t = \cdot 000143 \, n \, (t - t_a)$. A graph for calculating δt from this formula is given by Wheeler, *J.S.C.I.,* 1916, **35**, 1198.

The following table gives values of δt in °C. found experimentally by Rimbach, 1890, for Jena glass thermometers with solid stems, with degree divisions 1 to 1·6 mm. apart. The correction for German sleeve-thermometers may be up to 0°.25 C. less for $n=140$. Sleeve-thermometers are not, however, as reliable for high temperatures as solid-stem thermometers.

The most accurate method of making the correction is, however, that suggested by Guillaume, in which the mean temperature of the emergent column is indicated by the

mercury in a piece of thermometer tubing with no bulb (preferably of the same bore and same glass), which is placed alongside the thermometer with its meniscus level with that being read, and its closed lower end reaching into the hot fluid. The graduations of the "stem thermometer" are of course very close together. The difference between the temperatures registered by the two thermometers multiplied by $l/_{L-l}$ is the required correction: L and l are the lengths of a degree on the main and "stem" thermometers respectively.

-n.	$t-t_a$ in °C.								
	70	80	90	100	120	140	160	180	200
10	0.02	0.03	0.05	0.07	0.11	0.17	0.21	0.27	0.33
20	0.13	0.15	0.18	0.22	0.29	0.38	0.46	0.53	0.61
30	0.24	0.28	0.33	0.39	0.48	0.59	0.70	0.78	0.88
40	0.35	0.41	0.48	0.56	0.68	0.82	0.94	1.04	1.16
50	0.47	0.53	0.62	0.72	0.88	1.03	1.17	1.31	1.44
60	0.57	0.66	0.77	0.89	1.09	1.25	1.42	1.58	1.74
70	0.69	0.79	0.92	1.06	1.30	1.47	1.67	1.86	2.04
80	0.80	0.91	1.05	1.21	1.52	1.71	1.94	2.15	2.33
90	0.91	1.04	1.19	1.38	1.73	1.96	2.20	2.42	2.64
100	1.02	1.18	1.35	1.56	1.97	2.18	2.45	2.70	2.94
110				1.78	2.19	2.43	2.70	2.98	3.26
120				1.98	2.43	2.69	2.95	3.26	3.58
130				—	2.68	2.94	3.20	3.56	3.89
140					2.92	3.22	3.47	3.86	4.22

Correction of Boiling Points for Pressure.

(Mostly after S. Young).

If a temperature $t°$ C. be observed as the boiling point of a liquid under the pressure of p mms. of mercury at 0° C. the correction δt to be added to the observed b.p. to reduce it to that under the normal pressure of 760 mms. of mercury is $\delta t = c (760 - p) (273 + t)$.

The average value of c is 0·000120 : this is correct within 1×10^{-6} for bromine, stannic chloride, n-heptane, n-octane, benzene, toluene, ethyl benzene, naphthalene, ethylene dibromide, the mono-haloid-benzenes, and ethyl ether. More

accurate results are given in the cases below by the following constants :—

	$c \times 10^6$		$c \times 10^6$
Nitrogen	145	Anthracene	108
Argon	138	m-xylene	115
Chlorine	126	Triphenyl methane	108
Iodine	116	Naphthalene	119
Ammonia	110	Methyl chloride	126
Sulphur dioxide	113	Bromonaphthalene	115
Carbon disulphide	127	Methyl alcohol	100
,, tetrachloride	123	Ethyl ,,	94
Phosphorus trichloride	123	Propyl ,,	94
Silicon tetrachloride	126	Amyl ,,	98
Water *	99	Phenol	107
All esters	114	Acetic acid	107
Methane	135	Phthalic anhydride	112
n-pentane	125	Acetone	115
n-hexane	122	Benzophenone	109
iso-pentane	127	Anthraquinone	113
Di-iso-butyl	125	Aniline	112
Hexamethylene	124	Quinoline	115

Structurally similar substances have the same value of c.
* See table following

Boiling Point of Water at different Pressures.
(Broch).

mm.	°C.	mm.	°C.	mm.	°C.	mm.	°C.
700	97.72	720	98.50	740	99.26	760	100.00
1	76	1	54	1	30	1	04
2	80	2	58	2	33	2	07
3	84	3	61	3	37	3	11
4	88	4	65	4	41	4	15
5	92	5	69	5	44	5	18
6	96	6	73	6	48	6	22
7	98.00	7	77	7	52	7	26
8	03	8	80	8	56	8	29
9	07	9	84	9	59	9	33
710	11	730	88	750	63	770	36
1	15	1	92	1	67	1	40
2	19	2	96	2	71	2	44
3	23	3	99	3	74	3	47
4	27	4	99.03	4	78	4	51
5	31	5	07	5	82	5	55
6	34	6	11	6	85	6	58
7	38	7	14	7	89	7	62
8	42	8	18	8	93	8	65
9	46	9	22	9	96	9	69

Constant-Boiling Mixtures.

(Mostly after S. Young).

I. *Mixtures of Minimum Boiling Point*
(i) *Binary mixtures.*

Mixture.		Boiling points °C.			% by wt. of A in mixture.
A.	B.	A.	B.	Mixture.	
Water	Ethyl alcohol	100.0	78.39	78.13	4.41
	n-propyl alcohol ..	100.0	97.2	87.7	28.31
	iso-propyl alcohol ..	100.0	82.45	80.35	12.10
	n-butyl alcohol	100.0	117.5	92.25	37
	tert-butyl alcohol ..	100.0	82.55	79.9	11.76
	Allyl alcohol	100.0	97.08	88.0	28
	Butyric acid	100.0	159.5	99.2	80
	Pyridine	100.0	115	92.5	41
	Methyl ethyl ketone	100.0	79.57	73.57	11.4
	Ethyl acetate	100.0	77.15	70.37	8.43
Benzene	Methyl alcohol	80.2	64.7	58.35	60.45
	Ethyl alcohol	80.2	78.3	68.25	67.64
	n-propyl alcohol ..	80.2	97.2	77.1	83.1
	iso-propyl alcohol ..	80.2	82.45	71.9	66.7
	iso-butyl alcohol ..	80.2	108.05	79.85	90.7
	tert-butyl alcohol ..	80.2	82.55	73.95	63.4
	Allyl alcohol	80.14	97.06	76.75	82.6
	n-hexane	80.2	68.95	—	—
	Carbon tetrachloride	80.2	76.75	—	—
Toluene	Ethyl alcohol	110.6	78.3	76.7	—
	n-propyl alcohol ..	109	95.7	91.5	47
	iso-butyl alcohol ..	109	105.8	100	57
	Allyl alcohol	109	95.5	91.5	50
Methyl alcohol .	*n*-hexane	64.7	68.95	50.0	—
	Chloroform	64.7	60.5	54.0	12
	Carbon tetrachloride	64.7	76.75	55.7	20.6
	Ethyl bromide	64.7	38.0	35.5	5
	,, iodide	64.7	72.9	55	17
	Methyl acetate	64.7	56.0	54.0	18
	,, cyanide	64.8	81.6	63.7	77
	iso-butyl iodide	64.7	118.5	64.0	—
	Acetone	65.5	56.6	55.95	13.5
Ethyl alcohol ..	*n*-hexane	78.3	68.95	58.65	21
	Chloroform	78.3	61.15	59.4	7
	Carbon tetrachloride	78.3	76.8	65.2	16.0
	Ethyl bromide	77.8	38.0	37.0	—
	,, iodide	77.8	72.0	63.0	14
	iso-butyl iodide	77.8	118.5	77.0	70

Binary mixtures—continued.

| Mixture. | | Boiling points °C. | | | % by wt. of A in mixture. |
A.	B.	A.	B.	Mixture.	
Ethyl alcohol ..	Methyl cyanide	78.4	81.6	72.6	55
	Ethyl acetate	78.39	77.15	71.81	30.98
	Carbon disulphide..	77.8	45.7	42.0	9
n-propyl alcohol	n-hexane	97.2	68.95	65.65	—
	Ethyl iodide	95.7	72.4	70.0	7
	iso-butyl iodide	95.7	118.5	93.0	45
	Amyl bromide	95.5	118.2	94.0	70.7
	,, iodide	95.7	146.5	95.6	93
iso-propyl alcohol	Ethyl iodide	81.5	72.0	66.0	66
	iso-butyl iodide	81.5	118.5	81.5	70
	Ethyl acetate	81.5	76.0	74.5	26
	Carbon disulphide..	81.5	45.7	44.0	9
iso-butyl alcohol	n-hexane	108.05	68.95	68.1	—
	Ethylene dibromide	105.8	129.5	105.0	62
	iso-butyl iodide	105.8	118.5	101.5	—
	Amyl bromide	105.0	118.1	103.4	63.6
	,, iodide	104.8	146.5	104.7	95
Amyl alcohol ..	o-xylene	128.5	140.5	127.5	—
	m-xylene	128.5	136.5	125.5	52
	p-xylene	128.5	137.2	125.5	52
	Ethylene dibromide	128.5	129.5	121.5	30
	iso-butyl iodide....	128.5	118.5	115.5	—
	Amyl bromide	129.0	117.9	116.15	12.7
	,, iodide	128.9	146.5	127.3	52
Acetic acid	Benzene	118.5	80.2	80.05	2
	Toluene	117.5	109	104	30
	m-xylene	117.5	136.5	114	27
Butyric acid ..	Brombenzene	159.5	152.5	147.5	19
Acetone	Carbon disulphide..	56.4	46.2	39.25	34
	Methyl acetate	56.0	56.0	55.5	—
	Ethyl iodide	56.0	72.0	55.5	60
	Diethylamine	56.1	55.5	51.35	61.8
Carbon disulphide	Methylal	46.2	42.05	37.25	—
	Methyl acetate	45.6	56.0	39.5	71
	Ethyl acetate	45.6	76.0	46.0	92
	Ethyl bromide	45.6	38.0	37.5	32
	Ethyl ether	46.2	34.6	34.5	—
Ethyl acetate ..	Ethyl iodide	76.0	72.0	70.0	22
	Carbon tetrachloride	77.15	76.75	74.8	—

(ii) *Ternary Mixtures*.

Mixture.	Boiling points °C. Components.	Mixture.	Composition % by weight
Water	100.0		7.4
Benzene	80.2	64.85	74.1
Ethyl alcohol	78.3		18.5
Water	100.0		7.5
Iso-Propyl alcohol	82.45	66.5	18.7
Benzene	80.2		73.8
Water	100.0		—
Ethyl alcohol	78.3	56.6	—
n-Hexane	68.95		—
Water	100.0		9.0
Ethyl alcohol	78.39	70.23	8.4
Ethyl acetate	77.15		82.6
Water	100.0		3.4
Ethyl alcohol	78.3	61.8	10.3
Carbon tetrachloride	76.8		86.3
Water	100.0		8.1
Tert-butyl alcohol	82.55	67.3	21.4
Benzene	80.2		70.5
Water	100.0		8.6
n-Propyl alcohol	97.2	68.5	9.0
Benzene	80.2		82.4
Water	100.0		—
n-Propyl alcohol	97.2	59.95	—
n-Hexane	68.95		—
Water	100.0		8.58
Allyl alcohol	97.06	68.21	9.16
Benzene	80.14		82.26
Acetone	—		67.8
Methyl acetate	—	54.9	8.9
Methyl alcohol	—		23.3

II. *Mixtures of Maximum Boiling Point.*

| Mixture. | | Boiling points °C. | | | % of A by wt. in mixture. |
A.	B.	A.	B.	Mixture.	
Water	Nitric acid	100.0	86.0	121.7	31.82
	Hydrochloric acid..	100.0	– 80	110	79.76
	Hydrobromic acid..	100.0	– 73	126	52.5
	Hydriodic acid	100.0	– 35	127	43
	Hydrofluoric acid ..	100.0	19.4	120	63
	Formic acid	100.0	99.9	107.1	23
	Perchloric acid	100.0	110	203	28.4
Pyridine	Formic acid	117.5	100.0	149	—
	Propionic acid	117.5	140	149	—
Picoline	Acetic acid	134	118	145	—
Methyl ether ..	Hydrochloric acid..	– 21	– 80	– 2	61
Chloroform	Acetone	61.2	56.4	64.7	80
	Methyl acetate	60.5	56	64.5	78

Some High-boiling Aqueous Solutions.
(After Gerlach 1887).

Concentrations in gms. anhydrous salt per 100 gms. water. Saturated solutions are indicated by *, the corresponding b.p. being in brackets. The figures appear to be only rough approximations: different observers give sometimes widely different figures.

°C.	120	140	160	180
$CaCl_2$	69	137	222	*305 (178°)
Citric acid	478	1720	∞ (166°)	—
K acetate	134	309	609	626 (161°)
K_2CO_3	128	219 (133°)	—	—
KOH	57	92	122	153
$MgCl_2$	49	63 (130°)	—	—
Na acetate	146	—	—	—
$NaNO_3$	*222	—	—	—
NaOH	51	93	151	230
$Na_2S_2O_3$	214	*348 (126°)	—	—
NaK tartrate	390	1087	6666	∞ (165°)
NH_4NO_3	248	682	1370	2400 (explosive)
Pb acetate	3226	∞ (133°)	—	—
Tartaric acid	374	980	3774	∞ (170°)

Potassium sulphocyanide has been recommended as a constant-temperature bath between 100° and 200° C. or higher: up to 140° or so the temperature may be kept roughly constant by means of a constant-level arrangement which fixes the volume and hence the concentration and boiling-point.

CRYSTALLOGRAPHY.

E. H. Rodd, D.Sc.

The great advances in the technique of crystallography which have been made during the past few years have not only resulted in the gain of a much clearer insight into the structure of crystalline matter, but have pushed the boundaries of the science far into the territory of what was formerly supposed to be amorphous matter. On the one hand, the discovery of "fluid crystals" by Lehmann showed that some of the principal features of a crystal can be retained by matter in the fluid condition, and on the other hand it has been shown, by means of X-ray photographs, that such an apparently formless material as soot possesses a minutely crystalline structure. For most practical purposes, however, the old conception of a crystal suffices. A crystal, as distinct from crystalline matter, may be defined as a homogeneous solid body bounded by plane surfaces, the geometrical and physical properties of the body being, in general, different in different directions.

Symmetry. The number and distribution of the plane bounding surfaces or faces of a crystal are found always to conform to some geometrical law, and are consistent with the presence in the structure of some symmetrical homogeneous arrangement of the structural units. The character of the symmetry of a crystal can be determined more or less completely by a study of the distribution of the faces, although frequently assistance must be sought for its complete determination in other physical properties (optical, electrical, thermal, mechanical, etc.), which vary in magnitude according to the different directions in a crystal in which they are measured. Crystals are classified according to their degree of symmetry.

Elements of Symmetry. These are best considered in relation to a homogeneous structure of supposed indefinite extent, *e.g.*, a regular point system. A crystal is such a structure bounded by plane surfaces, the number and distribution of which depend directly upon the symmetry elements of the homogeneous structure.

There are three kinds of symmetry, axes, planes or a centre.

An *axis* of symmetry may be 2, 3, 4 or 6 fold, according to the number of times the structure repeats itself, *i.e.*, comes into a position indistinguishable from that from which it started, during a complete revolution of 360° about that axis. In addition to a simple axis of rotation, a second kind of axis, termed a screw axis, is possible, which combines a rotation and a simultaneous translation or progression along the direction of the axis.

Planes of symmetry are such that the structure on one side of the plane bears to that on the other side the same relation as that of an object to its mirror image.

The effect a *centre* of symmetry is that of a rotation through an angle of 180° combined with a reflection in a plane perpendicular to the axis of rotation. Points at opposite ends of a straight line passing through and bisected by a centre of symmetry are therefore similar.

Classes and Systems of Symmetry

It has been proved mathematically that there are only 32 possible classes of crystal symmetry, each distinguished by the possession of a certain combination of symmetry elements, axes, planes or a centre. All known crystals belong to one or other of these classes, and representatives of most of the possible classes have been discovered among actual crystals; one class of the tetragonal system and two classes of the trigonal system have, however, not yet been identified. For convenience the 32 classes are grouped in seven different systems. In each system the class which possesses the highest symmetry is called the *holohedral* class: classes of lower symmetry are called *hemihedral* or *tetartohedral*, according to whether the degradation of symmetry leads to the suppression of one-half or three-quarters of the number of faces of the most general form of crystal face. A *hemimorphic* class is a special type of hemihedral class, in which one-half of the holohedral planes occur independently, grouped about one extremity of an axis of symmetry. A hemimorphic crystal cannot therefore possess a centre of symmetry.

Crystallographic axes. For descriptive purposes crystals are referred to a system of axes, generally three, except in the hexagonal system, where four are used. Whenever possible, geometrical axes of symmetry are chosen for these axes of reference, but in systems of low symmetry this becomes impossible, and the crystallographic axes are then chosen with reference to important planes developed on the crystal.

Characteristics of the Seven Crystal Systems.

I. The Cubic, Isometric or Regular system. This system comprises five crystal classes : *holohedral*; *gyroidal hemihedral*; *pentagonal hemihedral*; *tetrahedral hemihedral*; *tetartohedral*. The holohedral class possesses the full symmetry of the cube, namely, three four-fold, four three-fold and six two-fold axes, with nine planes of symmetry. Fig. 1 represents a cubic crystal on which are developed cube and rhombic dodecahedron faces; the four-fold axes emerge perpendicularly from the centre of each cube face; the three-fold axes at points such as A, at which three rhombic dodecahedron faces meet; and the two-fold axes emerge perpendicularly from the centre of each dodecahedron face.

Fig. I.

In the hemihedral and tetartohedral classes, certain of these elements of symmetry disappear, but the four three-fold axes are always present.

The three four-fold axes are chosen as the crystallographic axes for the cubic system. In fig. 1 these are shown dotted. They are all equal in length, and all at right angles.

II. The *Tetragonal* system. The crystals belonging to this system are referred to three axes, all at right angles, two being equal in length, the third unequal. The unequal or principal axis is one of four-fold symmetry in each of the seven classes belonging to this system, and there are also, in the holohaldral class, four two-fold axes at right angles to the principal axis, and five planes of symmetry, four of which intersect in the principal axis, the other being perpendicular to it. Fig. 2, shows a ditetregonal bipyramid; the planes and axes can be readily distinguished.
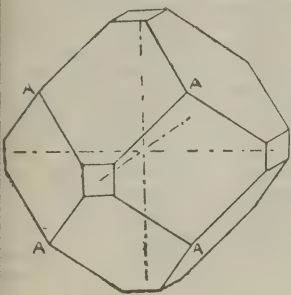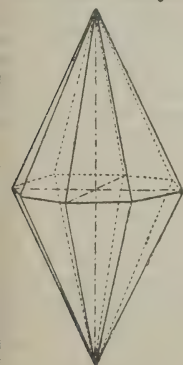
Fig. II.

III. The *Hexagonal* system. Crystals belonging to this system are referred to four axes. Three of these axes lie in a plane, making angles of 60° with one another; these are axes of two-fold symmetry in the holohedral class and are all equal. The fourth or principal axis is at right angles to the plane of the other three, and is unequal to them; its symmetry is six-fold. Fig. 3 represents a dihexagonal bipyramid. This system comprises five crystal classes.
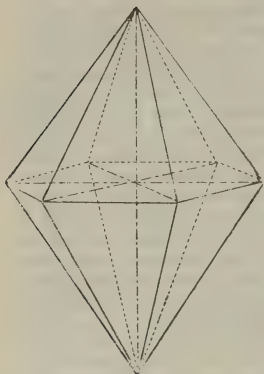
Fig. III.

IV. The *Rhombohedral* or *Trigonal* system. The seven crystal classes of this system are often grouped under the hexagonal system, being regarded as hemihedral hexagonal, the principal axis having been degraded from six-fold to three-fold symmetry. They are referred to the same system of axes as hexagonal crystals, or alternatively to a set of three oblique equal axes, the directions of which depend upon the angles of inclination of the faces of the fundamental rhombohedron. Fig. 4 shows a typical rhombohedron of calcspar, with the three-fold (trigonal) axis shown dotted.
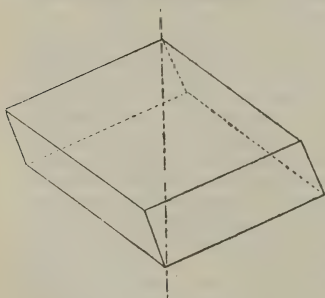
Fig. IV.

V. The *Rhombic* or *Orthorhombic* system. Crystals belonging to this system are referred to three axes at right angles, all unequal in length. In the holohedral class, these axes are of two-fold symmetry, and there are also three planes of symmetry and a centre. Fig. 5 shows a typical rhombic crystal of sulphur with the axes dotted in. This system comprises three classes: holohedral, hemihedral and hemimorphic.
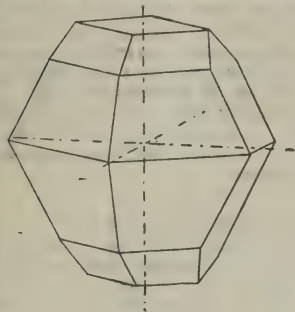
Fig. V.

VI. The *Monoclinic* or *Monosymmetric* system. Crystals belonging to this system possess only one axis of two-fold symmetry and one plane of symmetry perpendicular to this axis. The axis of symmetry is chosen as one crystallographic axis, *b*, the other two axes, *a* and *c*, being chosen arbitrarily in the symmetry plane. Hence, whilst *b* is at right angles to both *a* and *c*, these are inclined to one another at some angle β. Fig. 6 shows a crystal of ferrous sulphate in which the characteristic symmetry can be clearly seen, *bb'* being the axis of symmetry, the plane of symmetry being perpendicular thereto and containing the axes *a* and *c*. This system comprises three classes: holohedral; hemihedral, in which the axis of symmetry is lacking; and hemimorphic, in which the plane of symmetry is suppressed.
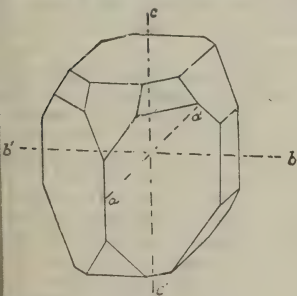
Fig. VI.

G

VII. The *Triclinic, Asymmetric* or *Anorthic* system. In this system there are neither planes nor axes of symmetry. The crystallographic axes are therefore chosen, in an arbitrary manner, with reference to certain faces developed on the crystal; they are all unequal and are not at right angles to one another. There are two classes of triclinic crystals; the holohedral class has a centre of symmetry, and each face on the crystal is accompanied by a corresponding parallel face; in the hemihedral class there is no centre, and any face may develop independently of any other.

The Law of Rational Indices and Crystal Notation.

The fundamental law which governs the development of faces on a crystal is the Law of Rational Indices. This empirical law states that the lengths of the intercepts of any face on the crystallographic axes must be simple multiples of the lengths of these axes. From this law has developed the current system of notation for crystal faces, now in such general use that other systems must be considered obsolete. Each face of a crystal is represented by indices which are reciprocals, reduced to their lowest terms, of the intercepts of the face on the three axes. If a, b, c are the axial lengths of a crystal and a face intercepts these axes at lengths, say, $3a$, $2b$, $3c$, the indices become $(\frac{1}{3}, \frac{1}{2}, \frac{1}{3})$, or, reduced to a common denominator, (232). A face which intercepts all three axes at unit length becomes (111).

In order to distinguish between different faces having the same indices, *e.g.*, the eight faces (111), negative signs are introduced. In fig. 7 the opposite ends of the three axes intersecting at O are given opposite signs in the conventional manner. A face intercepting $+a$, $+b$, $-c$ at unit length then becomes (11$\bar{1}$), that intercepting $-a$, $-b$, $-c$ is called ($\bar{1}\bar{1}\bar{1}$), and so on.
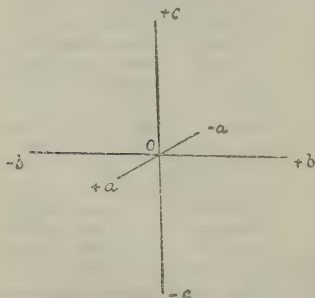
Fig. VII.

Pinacoid or *Basal Plane* faces, which intercept one axis and are parallel to the other two, receive indices (100), (010), (001)

Dome or *prism* faces, cutting two axes and parallel to the third, are of the type (110), (201), (032). For example, the rhombic dodecahedron of the cubic system is represented by twelve faces of the form (110), (011), (101), (1̄10), etc.

Pyramid faces, intersecting all three axes, are of the general form (*h k l*); *e.g.*, the octahedron of the cubic system is represented by eight faces (111), (1̄11), etc

Crystal Form.

If any one plane occurs as a crystal face, it must generally be accompanied by other faces in accordance with the symmetry of the class to which the crystal belongs. Thus if the face (111) develops on a holohedral cubic crystal, the other seven faces (11̄1), -(1̄11), etc., must also be present; if a cube face (100), develops, the other five cube faces (1̄00), (010), (001), etc., must appear. In the tetragonal system, however, (001) is accompanied only by (001̄), not by (100) and (010), since the axis *c* is not equivalent to *a* and *b*. Such a complete group of faces is known as a *crystal form*.

Axial Ratios.

In the cubic system the axes are all equal, $a : b : c = 1 : 1 : 1$. In the other systems, in which two or more axes are unequal, their relative lengths are calculated from the inclinations of faces to the axes by the usual trigonometrical formulæ. In the tetragonal system they become $a : b : c = 1 : 1 : x$, or $: c = 1 : x$, since *a* and *b* are equivalent.

In the hexagonal and trigonal systems, also, $a : c = 1 : x$, *c* being the principal axis.

In the orthorhombic system, $a : b : c = x : 1 : y$.

In the monoclinic system, in which the angle between the axes *a* and *c* is not a right angle, the interaxial angle must be stated, thus: $a : b : c = x : 1 : y ; \beta = ?$

In the triclinic system, all three interaxial angles must be stated: $a : b : c = x : 1 : y ; a = ? ; \beta = ? \gamma = ?$

It is important to notice that in all systems except the cubic there is a certain amount of latitude in the choice of axial ratios for any particular crystal. Thus in the orthorhombic system, any pyramid face, *i.e.*, any face which cuts all three axes, may be chosen as (111). This face then determines the axial ratios, and other faces receive indices to correspond, *e.g.*, (121). (212). But if (121) were chosen as (111), the others become (212) and (414) respectively. The general considerations governing the choice of axial ratios usually lead to the simplest set of indices being assigned to the different faces of the crystal. The same applies to the choice of suitable axes in the monoclinic and triclinic systems.

Topic Axial Ratios or Topic Parameters.

For the purpose of comparing the crystals of related substances, topic parameters are often used. By calculating three numbers $\chi : \psi : \omega$ in the same ratio as the axial ratios, and the product of which is equal to the molecular volume, V, the dimensions of a parallelopipedal cell containing one molecular unit of the crystal are obtained. The formulæ for this calculation, in the general case of a triclinic crystal, are :

$$\chi = \sqrt[3]{\frac{a^2 V}{c \sin A \sin \beta \sin \gamma}}$$

$$\psi = \frac{\chi}{a}$$

$$\omega = c\psi$$

where β and γ are interaxial angles, and A is the angle between the pinacoid faces b (010) and c (001). In those systems in which the axes are all at right angles, sin A, sin β and sin γ are all equal to 1.

Optical properties. Cubic crystals, on account of their high symmetry, are always singly refracting. All others exhibit double refraction.

The principal axis of symmetry in tetragonal, hexagonal and rhombohedral crystals is a unique optic axis. Orthorhombic, monoclinic and triclinic crystals show two optic axes.

Crystals which exist in enantiomorphous forms have the power of rotating the plane of polarisation of light. This property is in some cases due to the enantiomorphous arrangement of the molecules in the crystal, as in quartz; in others to the asymmetry of the molecule, as in *d*- and *l*-tartaric acid.

Cleavage. Many crystals exhibit the property of readily cleaving along certain directions, the cleaved surface being perfectly plane and bright. The cleavage plane is always a possible crystal face with simple indices, and is generally developed as a face on the crystal.

Twinning. Twin crystals are formed by the simultaneous development of two individuals from a common plane, termed the twinning plane. At other times the crystals show complete interpenetration, and are known as penetration twins. Again, repeated twinning may lead to the production of an apparent individual of higher symmetry than that which the real individual crystals possess. Twinning can generally be detected through the presence of re-entrant angles.

Isomorphism. Two substances having the same or practically the same crystalline form are said to be isomorphous. Isomorphous substances generally have very nearly equal axial ratios, belong to the same class of symmetry, and form mixed crystals or parallel growths. Isomorphism is generally only found among substances having similar chemical structure, *e.g.*, the sulphates and selenates of potassium, rubidium and cæsium, or *p*-dichlor- and *p*-dibrombenzene.

Dimorphism. A substance which can crystallise in two distinct forms is said to be dimorphous; if in three forms, trimorphous, etc.

Isodimorphism. If two substances A and B crystallise in two- separate systems. and at the same time form mixed crystals in either or both of these systems according to the proportion of A or B present in the mixture, they are said to be isodimorphous.

Morphotropic relationships are frequently observed between crystals of substances which are closely related chemically, but not so closely as to give rise to isomorphism. Such relationships usually take the form of similarity between one or both axial ratios; or a certain change of chemical composition may produce elongation or contraction in one direction only in the crystal structure.

Construction of Crystal Axes.

In order to draw a crystal in the conventional manner, the crystallographic axes must first be constructed. This is done as follows: Two lines LL′ and KK′ are drawn at right angles, intersecting at O. KO is made = K′O, and KK′ is trisected. Vertical lines are drawn through K′ and K and the points of trisection, and below K′ K/H is made = $\frac{1}{2}$ K′O. The line HO is produced, and the lateral axis *a* obtained, its length being AA′. Next AS is drawn parallel to KK′, and SO joined, cutting the inner vertical line at T. TB is drawn parallel to K′K, and from B BB′ is drawn through O. This line BB′ is then the second lateral axis.

Fig. VIII

Below K KQ is made = $\frac{1}{2}$ KO, and OC and OC′ are made equal to OQ. The line CC′ is then the third, vertical axis.

The three lines AA′, BB′, CC′ represent the projection of three equal axes at right angles, the axes of the cubic system. They can be modified to give tetragonal or rhombic axes by changing the lengths of AA′ or CC′ according to the axial ratios, BB′ being kept constant.

To obtain monoclinic axes, in which the angle between the axes a and c is β, Oc is made = OC cos β and Oa = OA sin β. From c and a lines are drawn parallel to OA′ and OC, and from their point of intersection, D′D is drawn through O. This line gives the direction of the axis a inclined at an angle β to the axis c. The relative lengths of the axes are determined as for the orthorhombic system.

To draw the axes for a hexagonal crystal, of which the axial ratio $a : c$ is given, orthorhombic axes are first constructed having the ratios $\sqrt{3} : 1 : c$. The extremities of AA′, BB′ are joined to form a rhomb (Fig. 9). The lines OA, OA′ are then bisected, and through the points of bisection the lines $a_{\prime}$, $a_{\prime\prime}$ are drawn parallel to BB′. There is thus formed a hexagon, the diagonals of which are the projections of the three lateral hexagonal axes.
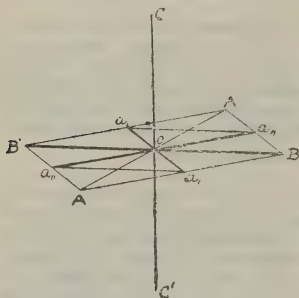
Fig. IX.

The construction of the crystal on the axes depends upon finding the lines of intersection of the various faces of the crystal, the intercepts of which upon the axes are known from their indices. This is done by the ordinary methods of solid geometry.

X-rays and Crystals.

Important discoveries have recently been made in connection with X-rays and crystals. A crystal acts towards X-rays as a three-dimensional diffraction grating, by virtue of the homogeneous arrangement of the atoms in the structure in series of consecutive planes in different directions. By studying the reflection of a pencil of monochromatic X-rays from crystal

faces, *i.e.*, from the important planes of atoms, an important relationship has been found between the angle of incidence which produces reflection, the wave-length of the X-rays, and the structure of the crystal. This law is expressed by the equation :

$$n \lambda = 2d \sin \theta,$$

where θ is the angle of incidence, λ is the wave-length, n is the order of the reflected spectrum, and d is the perpendicular distance between successive planes of atoms which give the reflection. It is evident that, when X-rays of known wave-length are used, and θ and n are determined experimentally, d can be calculated. In this way, great progress has been made with the intimate study of the internal structure of crystals. If d is determined in the three principal directions in the structure, the absolute dimensions of the unit parallelopipedal cell of the structure are found, and from the density of the crystal, and a knowledge of the mass of a hydrogen atom, the number of atoms or molecules in this crystal space unit can be determined. Researches along these lines with such crystals as rock salt, sylvine, diamond, pyrites and zinc blende have led to definite conclusions as to the disposition of the actual atoms in the crystals of each of these substances being drawn.

The reflection of X-rays by crystals has recently been applied by Hull in the development of a delicate method of chemical analysis (*J. Amer. Chem. Soc.*, 1919, **41**, 1168—1175). The specimen to be examined, of which only a minute quantity is required, is finely powdered and placed in a thin tube of glass or other truly amorphous material. A pencil of monochromatic X-rays is then caused to pass through the specimen, and the scattered rays impinge on a strip of sensitized photographic film. The film, when developed, shows a characteristic line spectrum, which is distinct for any pure chemical compound. From the character of spectrum given by the specimen, its purity can be gauged, and the nature of any impurity present can be told if its characteristic spectrum is known. This method, yet in its infancy, should be capable of further development.

Properties

	Name.	Composition.	(1) Cryst System.	Specific Gravity.	(2) Hardness
1	Acanthite	Ag_2S	I	7·2—7·3	2·5
2	Acmite (See Mono-clinic Pyroxene. Essentially Na_2O. $Fe_2O_3.4$ SiO_2				
3	Actinolite	See Amphibole.			
4	Adamine	$Zn_3(AsO_3)_2.H_2O$	IV.	4·3	3·5
5	Adularia	See Orthoclase.			
6	Aeschynite	$Ce_2(Ca, Fe)_2 (Ti, Th)_8$ $O_{21}.2Ce(CbO_3)_4$	IV.	4·9—5·1	5—6
7	Agalmatolite	$Al_2O_3.4SiO_2.H_2O$	I.	7·2—7·3	2·5
8	Agaric Mineral	See Calcite. White, earthy variety			
9	Agate	See Chalcedony and Silica.			
10	Aikenite	Bi_4S_3 with Pb and Cu	III.	9·7—9·8	2—2·5
11	Alabandin	MnS	tetr. h. I.	3·9—4·1	3·5—4
12	Alabaster	See Gypsum.			
13	Albite	$Al_2O_3.3SiO_2 + Na_2O.$ $3SiO_2$	VI.	2·59—2·65	6—7
14	Allophane	$Al_2O_3.SiO_2 + 5H_2O$	Am.	1·7—1·8	3
15	Almandine	$6FeO.3SiO_2 + 2Al_2O_3.$ $3SiO_2$	I.	3·7—4·21	6·5—7·5
16	Alstonite (Baryto Calcite)	$BaCO_3.CaCO_3$	V.	3·6	4
17	Altaite	PbTe	I.	8·16	3—3·5
18	Alum	$K_2SO_4.Al_2(SO_4)_3.$ $24H_2O$	I. pent. h.	1·75	2—2·5
19	Aluminite	$Al_2SO_6 + 9H_2O$	Am.	1·66	1—2
20	Alumstone	$3(Al_2SO_6) + K_2SO_4 +$ $6H_2O$	III.	2·58—2·75	3·5—4
21	Alumite	See Alumstone.	Rh. h.		

(1) *Crystallographic Systems* :—I. cubical (isometric) ; II. tetragonal ; III. hexagonal ; IV. rhombic ; V. monoclinic ; VI. triclinic. Am = amorphous ; h. = hemihedral ; t. = tetartohedral ; (h.) = hemimorphous ; pyr. = pyramidal ; rh. = rhombohedral ; sph. = sphenoid ; tetr. = tetrahedral ; trap. = trapezohedral ; pent. = pentagonal.

(2) *Moh's Mineralogical Scale of Hardness* :—(1) talc ; (2) rock-salt (or gypsum) ; (3) calc-spar (transparent variety) ; (4) fluor-spar (cryst. var.) ; (5) apatite (transparent crys. var.) ; (6) orthoclase ; (7) quartz (transparent var.) ; (8) topaz (cryst.) ; (9) sapphire (corundum) ; (10) diamond.

(3) *Lustre* :— Met. = metallic ; vit. = vitreous ; res. = resinous ; py. = pearly ; sy = silky ; ad. = adamantine ; wax. = waxy.

# of Minerals.

(3) Lustre.	(4) Colour.	Streak.	(5) Fracture.	(6) Fusibility.	(7) Solubility.	
Met.	B. Gr.	B.	Uneven	E fus.	E.s. in HNO_3	1
						2
Vit.	Gr.					3
Vit.	Y., R., Gr., Violet	Y.W.	$\infty P \overline{\infty}$ cryst.	B_1 fus.	E.s.HCl	4
	C. str.					5
Res.—sub. met.	Bl.—Br., Y.	Y. Br.		Inf.	decomp. H_2SO_4	6
Dull	Y. Gr. P. G.	B.	Uneven	E. fus.	E.s. in HNO_3 with sepn. of S.	7
						8
						9
Met.	W.—P.	W.—P.	Cryst.	E. fus.	s. in HNO_3	10
Sub. met.	Bl. Br.	Bl. Gr.	$\infty O \infty$	5	s. in HCl	11
	Pure W.					12
Py. or vit.	C. or W.	C.	Uneven v. brittle	D. fus.	gelatinous SiO_2 with HCl	13
Res. or wax.	W., P. Y. Gr. or Br	C.	Conch.	Inf.	gelatinous SiO_2 with HCl	14
Vit.	Deep R.	W.	Sub-conch. uneven	3	slight decomp. by HCl	
Vit. or res.	W. Gr. or Br.	W.	Uneven	D. fus.	E.s.HCl	16
Met.	W. Y.	W.	$\infty O \infty$	Fus.	E.s.HNO_3	17
Vit.	W.	C.	Cryst.	E. fus.	E.s.H_2O	18
Earthy	W.	W.	Earthy conch.	Inf.	s.HCl	19
Vit. or dull	W. Gr. or P	W.	Uneven or earthy	Inf.	D.s.H_2SO_4	20
						21

(4) *Colour* :—C. colourless; W. white; R. red; P. pink; B. blue; Y. yellow; G. green; Br. brown; Bl. black; Gr. grey.

Diaphaneity :—tr. = transparent; tl. = translucent; str. = subtransparent; stl. = subtranslucent; op. = opaque.

(5) *Fracture* :—Cryst. = crystalline fracture or cleavage; conch. = conchoidal.

(6) *Fusibility* :—(1) Antimony glance (antimonite); (2) natrolite (mesotype); (3) almandine garnet; (4) actinolite; (5) orthoclase; (6) Bronzite. Fus. = fusible; e. fus. = easily fusible; d. fus. = difficultly fusible; inf. = infusible.

(7) *Solubility* :—s. = soluble; e.s. = easily soluble; d.s. = difficultly soluble. The name of the solvent is given after the degree of solubility, *e.g.*, d. sol. HNO_3 = difficultly soluble in HNO_3.

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Alum, Ammonia	$(NH_4)_2SO_4.Al_2(SO_4)_3$ 24 H_2O	I. pent. h.	1·63—1·75	1·5
2	— Iron	$FeSO_4.Al_2(SO_4)_3.$ 24 H_2O	I	1·712	1·7
3	— Soda	$Na_2SO_4.Al_2(SO_4)_3$ 24 H_2O	I. pent. h.	1·6—1·8	2·0—2·5
4	— Magnesia	$MgSO_4.Al_2(SO_4)_3$ 18 H_2O	I.	1·53—1·8	1·5—2·0
5	Alunogene	$Al_2O_3.SO_3+18 H_2O$	V	1·6—1·8	1·5—2·0
6	Amalgam	Ag with Hg	I. rh.	10·5—14	3—3·5
7	Amazonstone	See Microcline.			
8	Amber	Fossil resin, Bitumen class	Am	1·08	2—2·5
9	Amblygonite	$Li(Al,F)PO_4$	VI	3—3·11	6
10	Amblystegite	See Enstatite. (Contains more iron than Hypersthene			
11	Amethyst (Oriental or true)	Al_2O_3	III.	3·90—4·16	9
12	Amethyst	SiO_2 with Mn, or (Fe and Na)	III. rh.	2·5—2·8	7
13	Amianthus	See Asbestus (Silky variety)			
14	Amphibole	$Ca(Mg,Fe)_3(SiO_3)_4$ with $Na_2Al_2(SiO_3)_4$ and $(Mg,Fe)_2(Al,Fe)_4$ Si_3O_{12}	V	2·9—3·4	5—6
15	Amphigene	See Leucite.			
16	Analcime	$Al_2O_3.3SiO_2+Na_2O,$ $SiO_2+2 H_2O$	I. trap.	2·22—2·29	5—5·5
17	Anatase	TiO_2	II. pyr.	3·75—3·9	5·5—6
18	Andalusite	$Al_2O_3.SiO_2$	IV	3·1—3·3	7·5
19	Andesine	See Felspar. (Between Oligoclase and Labradorite)	VI.	2·6—2·7	5—6
20	Andradite	See Garnet, Iron-lime.			
21	Anglesite	$PbSO_4$	IV.	6·12—6·39	2·75—3
22	Anhydrite	$CaSO_4$	IV.	2·8—2·97	3—3·5
23	Ankerite	$(Ca,Fe,Mg,Mn) CO_3$	III.rh.h.	2·9—3·2	3·5—4
24	Annabergite	$Ni_3As_2O_8+8H_2O$	V.	3—3·1	2—2·5
25	Annerödite	$(U,Y,Th,Ce,&c.)$ $(NbO_2)_2$	IV.	5—6	5
26	Anomite	Contains lithium.	See Biotite.		
27	Anorthite	$Al_2O_3.SiO_2+$ $CaO.SiO_2$	VI.prism	2·66—2·78	6—7
28	Anorthoclase	$Na_2O.2SiO_2+$ $Al_2O_3.4SiO_2$	VI.	2·6·	6
29	Anthophyllite	$(Mg,Fe) O.SiO_2$	IV.	3·2	5·5
30	Anthracite	C(95 per cent.)	Am.	1—1·8	2—2·5
31	Anthraconite	$CaCO_3$ with bituminous matter	Am.	2·6—2·7	2·5
32	Antimony	Sb	III.rh.	6·6—6·7	3—3·5
	Antimony Blende, (antimonite, stibnite, antimony glance, grey antimony).	Sb_2S_3	IV.	4·5—4·6	2

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit.	W.	W.	Am.	E. fus.	E.s. H_2O	1
Vit.	Violet	W.	Am.	E. fus.	E,s, H_2O	2
Soapy	C.W.		Am.	E. fus.	E,s. H_2O	3
	W.					4
Vit.—sy.	W., Y., P.	W.	Am.	Inf.	s. HCl	5
Met.	Silver W.	W.	Conch. uneven	E. fus.	E.s. HNO_3	6
	G.					7
Wax	Y.—W.	W.	Conch.	Burns.	Ins.	8
Vit. py.	W., G.	W.	oP.	E. fus.	d.s. H_2SO_4	9
Pleochroi	c).			6		10
-Vit.	Purple	W.	Conch.	Inf.	Ins.	11
Vit.	Purple	W.	Cryst. or conch.	Inf.	sol. HF	12
						13
Vit., res., or earthy	G., Gr., Bl.	Gr., G.	∞ P. 124°	E. fus.	gelatinous SiO_2 with HCl	14
						15
Vit.	W., tr., tl., or op.	W.	Sub. conch. or uneven	2·5	gelatinous SiO_2 with HCl	16
ad. met.	G.,Br.,Bl.,B.	Gr., W.	oP, P.	Inf.	Ins.	17
Vit.	Gr., P., Br.	W.	Uneven tough	Inf.	E.s. H_2SO_4 and HF	18
Vit.	C., W., G.	W.		4	Ins.	19
						20
Ad. res. or vit.	Wine Y. W. tinted Y., R., B., Gr.	C.	Conch. v. brittle	E. fus.	d.s. HCl, s. KOH	21
Py. or vit.	W.	Gr., W.	Uneven and splintery	3·5	d.s. H_2O, s. HCl	22
Vit.	Y., Gr., Br.	Y., W.	Brittle	Inf.	s. HCl	23
Matt.	G. (apple), W.	G., W.	Earthy	E. fus.	E.s. HCl	24
Met.	Bl.	Bl.	Conch.	Inf.		25
						26
Vit. py.	W., C., and milky	C., W.	Conch.	3	s. conc. HCl	27
Vit.	C., W., R.	C.	oP, ∞P∞	4	Ins.	28
Vit. py.	Br., Gr.	Br., W.	∞P∞	5	Ins.	29
Vit. sub.— met., res.	Bl.	Bl., Gr.	Conch. uneven	Burns	Ins.	30
Earthy	Gr., Br.	Gr.	Conch.	Inf.	s. HCl	31
						32
Met.	Tin W.	Tin W.	Very cryst.	1—1·5	s. hot HCl $SbCl_3$ separates	
Met.	Lead Gr.	Gr.	Sectile	1	s. hot HCl	33

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Antimonate, Calcium (Romeite)	$3CaO.Sb_2O_3$	II.		
2	— Copper (Rivotite)	$3CuO.Sb_2O_3 + CuCO_3$	II.		
3	— Lead	(Several exist, of varying composition, some containing			
4	Antimonious nickel	NiSb	III.	7·5	5·5
5	Antimony ochre	Sb_2O_4	?	3·7—3·8	1
6	Antimonial nickel-sulphide	See Ullmannite.			
7	Antimonial silver	See Dyscrasite.			
8	Apatite	$3(Ca_3P_2O_8) + CaCl_2$ (Cl variety) $3(Ca_3P_2O_8) + CaF_2$ (F variety)	III.	2·92—3·25	5
9	Aphanesite	$2CuO.As_2O_3 + 4H_2O$	IV.	4·19—4·36	2·5—3
10	Aplome	See Garnet, Iron-lime.			
11	Apophyllite	$K_2O.8CaO.16SiO_2$ $16H_2O$	II.	2·3—2·4	4·5—5
12	Aquamarine	See Beryl.			
13	Aragonite	$CaCO_3$	IV.	2·93	3·5—4
14	Arendalite	See Epidote. Fine crystallised form.			
15	Arfvedsonite	Amphibole with soda	V.	See Amphibole.	
16	Argentine	See Calcite (Lamellar, white, shining variety)			
17	Argentite	Ag_2S	I.	7·19—7·36	2—2·5
18	Argentopyrites	$3FeS.3FeS_2.Ag_2S$	IV.	6·47	3·5—4
19	Arkansite	See Brookite (Thick iron—black crystals).			
20	Arsenate of Cobalt	See Erythrine.			
21	— Copper	$2CuO.As_2O_3 + 4H_2O$	IV.	3·4	3·5
22	— Iron	$2FeO.As_2O_3$	IV.	3·1—3·3	3·5—4
23	— Lead	See Mimetite.			
24	— Zinc	See Adamine.			
25	Arsenic (Native)	As.	III.rl.	5·93	3·5
26	— (White)	As_2O_3	I.	3·7	1·5
27	Arsenical Antimony	Sb_2As_2	IV.	Also known as	
28	— cobalt	See Smaltine.			
29	— iron ore	See Mispickel.			
30	— lead ores	See Freislebenite			
31	— nickel	See Kupfernickel.			
32	Arsenical iron (Löllingite)	$FeAs_2$	IV.	7—7·4	5—5·5
33	Arsenical pyrites	See Mispickel.			
34	Arsenolite	See Arsenic (White)			
35	Arsenopyrites	See Mispickel.			
36	Asbestos	Fibrous Actinolite, Grammatite, and Tremolite.	V.	2·9	
37	Asbolane	See Earthy Cobalt.			
38	Asparagus Stone	See Apatite (Pale yellowish - green variety).			
39	Asphaltum	75%—88%C. Mixture of hydrocarbons, partly oxidised)	Am.	1—1·7	1—2

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Earthy	Y.	Y.		3—4		1
	Y.—G.	G.				2
ing chlorine	and some silic	a.)				3
Met.	Copper R.	P.	Cryst.	d, fus.	E.s. HNO₃	4
Dull	Y.	Y.	Earthy	Inf.	s. hot HCl	5
						6
						7
Vit. or res.	W., C., tr. G., Br., B., op.	W.	Conch. brittle	!—5	s. HCl	8
Vit.	Dark G.—B.	G.	Conch. uneven	fus.	s. HNO₃	9
	R.					10
Vit. or py.	W., C., G., Gr., Y., R., tr. or tl.	C.	oP	3	gelatinous SiO₂ with HCl	11
	Pale B.					12
Vit.	C., W., Y., P., Gr.	C.	Conch. brittle	Inf.	E.s. HCl	13
	Bl., G.					14
						15
						16
Met.	Bl., Lead Gr.	Gr. shining	sub. conch. or uneven sectile	Fus.	s. HNO₃	17
Met.	W., Y., Br.	Bl.	oP	E. fus.	decom. HNO₃	18
						19
						20
Vit.	G.	G.	Conch.	E. fus.	s. HNO₃	21
Vit.—ad.	Leek G. or liver Br.	G.	Conch.	Fus.	s. HNO₃	22
						23
						24
Met.	W. tarnishes Gr.	Tin W.	Uneven, granular, brittle	Volatilises	s. HNO₃ with sepn. of As₂O₃	25
Dull Allemontite.	W.	C.	Earthy.	Volatilises	D.s. H₂O	26
						27
						28
						29
						30
						31
Met.	W., Gr.	Bl	oP	d. fus.	s. HNO₃ with sepn. of As₂O₃	32
						33
						34
						35
Sy.	W.,G.,Y.,Br.		Fibrous	d. fus.	d. decomp.	36
						37
						38
Oily	Br., Bl.	Bl.	Conch.	100° C.	s. ether	39

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Astrachanite	See Blödite.			
2	Astrophyllite	$(Fe,Mn)_4(Na,K,H)_4$ $(Si,Ti,Zr)_5O_{16}$	IV.	3·3—3·4	3·5
3	Atacamite	$CuCl_2+3Cu(OH)_2$	IV.prls.	3·76—4·3	3—3·5
4	Auerbachite	$ZrSiO_4$	Am.		
5	Augite	$CaO.MgO.2SiO_2$ with $(Mg,Fe)O.(Al,Fe)_2O_3$ SiO_3. A pyroxene.	V.	3·2—3·5	6
6	Aurichalcite	$2(Zn,Cu)CO_3.$ $3(Zn,Cu)(OH)_2$	?	3·43—3·6	2
7	Automolite	$ZnO.Al_2O_3$	I.	4—4·6	7·5—8
8	Autunite	$(CaO+3U_3O_8)P_2O_5+$ $8H_2O$	IV.	3·05—3·19	2—2·5
9	Aventurine Felspar	See Felspar (Minute disseminated crystals of specular			
10	— Quarz	SiO_2 with spangles of golden-yellow or brown mica	III.rh.	2·5—2·8	7
11	Axinite	$H_2(CaFeMn)_4(BO)$ $Al_3(SiO_4)_5$	VI.	3·27	6·5—7
12	Azorite	$ZrSiO_4$	II.		
13	Azurite	$2CuCO_3.Cu(OH)_2$	V.	3·5—3·8	3·5—4·25
14	Babingtonite	$(Ca,Fe,Mn)O.SiO_2$; $Fe_2O_3.3SiO_2$	VI.	3·3—3·4	5—5·5
15	Baddeleyite (Brazilite)	$ZrO_2(96·5\%)$ contg. Al,Fe,Mg,K,Na,Si	V.	5—6	6·5
16	Bagrationite (Allanite)	Cerium epidote	V.	3—4·2	5·5—6
17	Baikalite	See Diopside			
18	Balas Ruby	See Spinel.			
19	Barcenite	$3HgO,Sb_2O_3$	Am.	5·343	5·5
20	Barylite	$2BaO.SiO_2$	Am.	4·03	7
21	Barytes	$BaSO_4$	IV.	4·3—4·7	2·5—3·5
22	Baryto-Calcite	See Alstonite.			
23	Basanite	See Jasper (used for streak plates for testing gold a			
24	Bastite	See Schillerspar.			
25	Bastnäsite (Hamartite)	$[(Ce,La,Di)F]CO_2$	III.	4·93—5·18	4—4·5
26	Beauxite	$Al_2O_3.2H_2O$	Am.		
27	Beccarite	ZrO_2			8
28	Bell-metal ore	See Stannine.			
29	Beryl	$3BeO.SiO_2+Al_2O_3.$ $3SiO_2$	VI.	2·63—2·75	7·5—8
30	Beyrichite	See Millerite.	III.rh.h.		
31	Bieberite	$CoSO_4.7H_2O$	VI.		
32	Binnite	$2As_2S_3.3Cu_2S$	I.tetr.h.		
33	Biotite	$(K,H)_2O.(Mg,Fe)_2O_3$ Al_2O_3	V. V.	2·7—3·2	2·5—3
34	Bismite	See Bismuth Ochre.			
35	Bismuth, Native	Bi	III.rh.	9·7—9·8	2—2·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
						1
Vit.	Br.Y., Y., R.Br.	Pale Br.	$\infty \bar{P}\infty$	E. fus.		2
Ad.—vit.	G.—Bl.G., bl.— stl.	Apple G.	$\infty P\overline{\infty}$	Fus.	s. HNO_3	3
Earthy	Br., Gr.	Br.				4
Vit.—res.	Bl. & G.Bl.	W., Gr.		3·5	de. dcomp.	5
Py.	Pale G.-sky B.	B., W.		Inf.	s. HCl	6
Vit.	Dark G.—Bl.	G.	Conch.	Inf.	Ins.	7
Sub. ad.	Citron-sulphur Y.	Y.W.	oP; $\infty P\overline{\infty}$	E. fus.	s.HNO_3	8
or titanic iron or limonite).						9
Vit.	C. tl.	C.	Conch.	Inf.	s.HF	10
Highly vit.	Clove Br., plum Br., py. Gr.	C.	$\infty P\overline{\infty}$	2	Gelatinous SiO_2 with HCl.	11
Ad. vit.	Gr. G.					12
Vit.—sub. ad.	Azure B., tr.—op.	Light B.	$P\infty$	2	S.HCl.	13
Vit.	G. Bl.	G.Gr.	oP; $\infty P\overline{\infty}$	E. fus.	Ins.	14
Fatty, sy.	Y., Br., Bl.	Br.; W.	Conch. uneven			15
Sub. met.—res.	Bl.—pinchbeck Br.	Br.	Cryst.	E. fus.	Gelatinous SiO_2 with HCl.	16
						17
	Rose R.					18
Earthy	Gr. Bl.	Gr.	Earthy	E. fus.	Sol.HNO_3	19
Earthy	C.	C.	Earthy	Inf.		20
Vit. res. py.	W., C.	W.	oP ; ∞P.	5	S. hot H_2SO_4	21
loys)	Pure Bl.					22
						23
						24
Vit.	Y., R. Br.	Y. Gr.		Inf.	Decomp.HCl.	25
Earthy	W., Gr., Br., R., Y.	W., Br.	Earthy	Inf.	d.s. hot HCl. and hot H_2SO_4	26
Vit.	Olive G.	G.		Inf.	Ins.	27
						28
Vit. res.	G., B., Y., W.	W.	Conch. brittle	5·5	Ins.	29
						30
Vit.	Flesh or rose R.	P.	Conch.			31
Met.	Gr. Bl.	Br.	Conch.	E. fus.	Decomp. hot HCl. and KOH	32
Py. splendent	Bl., G., Br., R.	C.	oP	D. fus.	Decomp. H_2SO_4	33
						34
Met.	Silver W., P. tinge	As colour	oR—2R sectile	1	s.HNO_3	35

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Bismuth Nickel	Bi_6S_3 with NiS	III.	5·13	4
2	— Ochre	Bi_2O_3	IV. or Am.	4·36	1
3	— silver	Ag with 16% Bi; Ag_{10} Bi			
4	— gold	Au_2Bi		8·2—8·7	2
5	— Telluride	See Tetradymite.			
6	Bismuthinite	Bi_2S_3	Acicular crystals.		
7	Bismuthite—ine	Bi_2S_3	IV.	6·5	2—2·5
8	Bitter Spar	See Dolomite (ferruginous variety).			
9	Bitumen	Hydrocarbons, partly oxygenated		See Asphaltum.	
10	— elastic	As for Bitumen	Am.	0·9—1·25	0·5
11	Black cobalt	See Earthy Cobalt.			
12	Black jack	See Sphalerite.			
13	— lead	See Graphite.			
14	— silver	See Stephanite.			
15	— tellurium	$(Pb,Au,)(Te,S)$	II.	7·1	1—1·5
16	Blende	See Sphalerite.			
17	Blödite (Astrachanite)	$Na_2SO_4.MgSO_4.4 H_2O$	V.	2·25	2·5—3·5
18	Bloodstone	See Jasper.			
19	Blue iron ore	See Vivianite.	Earthy		
20	— copper	CuS	Am.	3·8	2·5—3
21	— John	See Fluor Spar.			
22	— vitriol	See Chalcanthite.			
23	Boghead coal	Cannel coal, high % ash.	Am.	1·4—1·7	
24	Bog iron ore	See Limonite.	Am.		
25	Bole	$4 Al_2O_3.9 SiO_2$	Am.	1·6—2·2	1—2
26	Bone turquoise	Fossil bones or teeth, coloured with $Fe_3P_2O_8$			
27	Boracic acid	$3 H_2O.B_2O_3$	VI.	1·48	1
28	Boracite	$6 MgO.MgCl_2.8 B_2O_3$	I. or Am.	2·95	4—5, crystals 7
29	Borax	$Na_2O.2B_2O_3.10 H_2O$	V. pris.	1·74	2—2·5
30	Borate, calcium-sodium	See Ulexite.			
31	— magnesium	See Boracite.			
32	Bornite	$2Cu_2S.Cu_2S_2.2 FeS$	I	4·9—5·4	3
33	Boronatrocalcite	See Ulexite.			
34	Bort	C, (compact variety of diamond, used for cutting prec			
35	Botryolite	See Datolite (Botryoidal).			
36	Boulangerite	$3 PbS.Sb_2S_3$	IV.	5·8—6	3
37	Bournonite	$3 (Pb,Cu_2)S.Sb_2S_3$	IV.	5·7—5·9	2·5
38	Bowenite	Serpentine		2·59—2·8	5·5—6

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
	Gr.—W.	W.	Conch.	Fus.	s.HNO_3	1
by	Gr., Y., G.	Y., W.	Earthy	Fus.	s.HNO_3	2
	W.	Met. W.		E. fus.	s.HNO_3	3
Met.	Y., W.	Met. Y.,W.		E. fus.	s.Aqua-regia	4
						5
	Lead Gr.	W., Gr.	Earthy			6
Met.	Lead Gr., Y.	Gr., Bl.	∞ P ∞	E. fus.	s.HNO_3 with sepn. of S.	7
						8
						9
Pitchy	Bl., Br.	Bl.	Elastic	E. fus, burns		10
						11
						12
						13
						14
Met.	Gr.	Gr., Bl.	∞ P ∞	E. fus.	s.HNO_3 with sepn. of Au.	15
						16
Vit.	C., G., Gr. P.	C.		Fus.	E.s.H_2O	17
	G. with R. spots					18
						19
Dull	Bl.—B.	Dark B.	Earthy	E. fus.	s.hot HNO_3 with sepn. of S.	20
						21
						22
Waxy	Bl.			Burns	Ins.	23
	Br., Bl.		Earthy, loose			24
Earthy	Br., Gr.	Gr.	Conch.	Inf.		25
	B.	W.				26
Py., TL, Tr.	C., W. Gr.	W.	∞P	2	E.s.hot H_2O	27
Vit.	C., W., Y., Gr., G., Tr. or op.	W.	Conch.	2	d.s.HCl.	28
Vit. or earthy	W., tinge B., G., Gr.	W.	Soft, brittle	E. fus.	s.H_2O	29
						30
						31
Met.	Copper R. or pinchbeck Br.	Gr., Bl., shining	Conch., uneven, small	2—3	s.HNO_3 with sepn. of S.	32
						33
ious stones	and drilling ro	cks)				34
						35
Sy. met.	Lead Gr.	Gr., Bl.	Uneven	1·5—2	s.hot HCl.	36
Met.	Lead Gr., Bl.	Gr.	Conch. brittle	1·5	s.HNO_3 with sepn. of S and Sb_2O_3	37
Aspect of N	ephrite					38

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Braunite	Mn_2O_3	II.	4·71—4·82	6—6·5
2	Bravaisite	Near Glauconite			1—2
3	Breithauptite	See Antimonious Nickel.			
4	Brewsterite	$(Ba,Sr)O.Al_2O_3.6 SiO_2 + 5 H_2O$	V.	2·45	4·5—5
5	Brittle silver ore	See Stephanite.			
6	Brochantite	$CuSO_4.3 Cu(OH)_2$	IV.	3·8—3·9	3·5—4
7	Bröggerite	$(U,Th,Pb_2)_3O_6.2 UO_3$	I.	8·7—9	5·5
8	Bromargyrite	See Bromite.			
9	Bromite (Bromyrite)	AgBr	I.	5·8—6	2—3
10	Bromlite	See Alstonite.	IV.		
11	Bronzite	$(Mg,Fe)O.SiO_2$	IV.	3·18—3·3	5·5
12	Brookite	TiO_2	IV.	3·8—4·2	5·5—6
13	Brown coal	See Lignite.			
14	Brown hæmatite	See Limonite.			
15	— ochre	See Limonite.	Am.		
16	— spar	Dolomite with Mn_2O_3, Fe_2O_3	III. rh.		
17	Brucite	$MgO.H_2O$	III. rh.	2·35	2
18	Bucholzite	See Fibrolite.			
19	Bunsenine	See Krennerite.			
20	Bytownite	Near Anorthite, more silica (46—48%) and some soda	VI.	2·75	6
21	Cacoxenite	$Fe_2O_3.P_2O_5 + 8 H_2O$	V.	3·38	3—4
22	Cairngorm	SiO_2	III. rh.	2·5—2·8	7
23	Calamine*	$ZnCO_3$	III. rh.	4—4·45	5
24	Calaverite	$AuTe_2$		9·043	1·5—2
25	Calcite	$CaCO_3$	III. rh.	2·6—2·7	2·5—3·5
26	Calc-spar	See Calcite.			
27	Caledonite	$(Pb,Cu)O.(Pb,Cu)SO_4.H_2O.$	V.	6·4	2·5—3
28	Calomel	Hg_2Cl_2	II.	6·5	1—2
29	Cancrinite	$(Na_2,K_2)_4O_4.4 Al_2O_3.9 SiO_2$ with Na_2CO_3 and water	III.	2·4—2·5	5—6
30	Cannel coal	50—60% hydrocarbons	Am.	About 1·5	1·5—2
31	Capillary pyrites	See Millerite.			
32	Carbonado	C. (diamond) (Used for cutting purposes.)			
33	Carbonate, barium	See Witherite.			
34	— bismuthite	See Bismuthite.			
35	— copper	See Malachite, Azurite.			
36	— iron	See Siderite.			
37	— lead	See Cerussite.			
38	— magnesium	See Magnesite.			
39	— manganese	See Rhodochrosite.			
40	— sodium	See Natron.			
41	— strontium	See Strontianite.			

*Calamine is taken as the English name. This is the Smithsonite of Dana

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Sub.—met. matt.	Br., Bl., Gr.	Br., Bl.	Uneven, brittle	Inf.	s.HCl.	1
	Gr.—G.	(Greasy feel)				2
						3
Vit. or py.	C., W., Gr., Y.	C.	$\infty P \infty$	Fus.	s.HCl. with sepn. of powdery SiO_2	4
						5
Vit.	Emerald G.	G.	$\infty P \infty$	E. fus.	s.HCl.	6
Fatty	Bl., G Bl., Gr. Bl.	Br., Bl.	Conch., uneven	Inf.	s.hot HNO_3	7
						8
Ad. or fatty	G., Y., Gr.	Y., G.	Conch.	2	s.NH_3 soln.	9
						10
Met.	Br., Y.		$\infty P \infty$, ∞P	6	Ins.	11
Met.—ad.	Rov. hair Br.	Br., Y.	Uneven	Inf.	Ins.	12
						13
						14
	Br., Y.		Earthy			15
	Br.					16
Vit. py.; Wax. or sy.	G., W., G. Te.—stl.	W.	oR	Inf.	s.HCl.	17
						18
						19
Vit.	W.		oP, $\infty P \infty$	3·5	d.decomp. HCl.	20
Sy.	Y.—Br.	Y.	Conch.	E. ius.	s.HCl.	21
Vit.	Smoky Y. or Br.		Conch.	Inf.		22
Vit. py.	W. (G. or Br.)	W.	Uneven, brittle	Inf.	s.Acids	23
Met.	Bronze Y.	Y.	Conch.	E. fus.		24
Vit.—earthy	C., W., tint P., Y., Gr.	W. or Gr.	Along cleavage planes	Inf.	s.Acids (acetic acid)	25
						26
Wax	B., G., G.	G., W.	$\infty P \infty$	Inf.	s.H_2SO_4 with sepn. of $PbSO_4$	27
Ad.	Gr., Y., W.		Conch., uneven	Sublimes	s.HNO_3 + HCl	28
Wax	W., Y., P., B.Gr.	C.	Uneven	V.E. fus.	s.acids	29
Dull, takes high polish	Bl., Br.	Br.	Conch.	Burns		30
						31
	Bl.					32
						33
						34
						35
						36
						37
						38
						39
						40
						41

and others.

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Carbonate yttrium	See Parisite.			
2	— zinc	See Calamine.			
3	Carnallite	$MgCl_2.KCl.6 H_2O$	IV. Am.	1·6	1
4	Carnelian	Chalcedony, SiO_2	III.rh.	2·4	7
5	Carpholite	$(Mn,Fe)O.(Fe,Al)_2O_3.$ $2 SiO_2 + 2 H_2O$	V.	2·7—2·9	5
6	Cassiterite	SnO_2	II.	6·4—7·1	6—7
7	Cat's eye	SiO_2 (minutely fibrous structure in side quartz crystals).			
8	Celestine	$SrSO_4$	IV.	3·9	3—3·5
9	Cerargyrite	See Horn Silver.			
10	Cerite	$2(Ca,Fe)O.3Ce_2O_3.$ $6SiO_2.3H_2O.$ $Ce = (Ce,La,Di).$	IV.	4·75—5·1	5·5
11	Cerussite	$PbCO_3$	IV.	6·5	3—3·5
12	Cervantite	Sb_2O_4 results from decomposition of stibnite.			
13	Chabazite	$(Ca,Na_2)O.Al_2O_3.$ $4 SiO_2.6 H_2O$	III. rh. h.	2·1—2·2	4·5—5
14	Chalcanthite	$CuSO_4.5 H_2O$	VI.	2·21	2—2·5
15	Chalcedony	SiO_2 (microcrystalline)	III.	2·6—2·65	7
16	Chalcocite	See Redruthite.			
17	Chalcolite	$CuO.UO_2.P_2O_5.8 H_2O$ contg. Ra	II.	3·4—3·6	2—2·5
18	Chalcomenite	$CuSeO_3.2 H_2O$	V.	3·76	
19	Chalcophanite	$Mn_2O_3.ZnO.xH_2O$	Am. or IV.	4·3	5—5·5
20	Chalcophyllite (Copper mica)	$2 CuO.As_2O_3 + xH_2O$	Foliated	2·43—2·66	2
21	Chalcopyrite	See Copper Pyrites.			
22	Chalcotrichite	Capillary Cuprite.			
23	Chalk	$CaCO_3$	Am.	Very variable	
24	Chalybite	See Siderite.			
25	Chamosite	$Al_2O_3.3 (Fe,Mg)O.$ $2 SiO_2.3 H_2O$			
26	Chert	Massive SiO_2	Am.	2·6—2·8	
27	Chessylite	See Azurite.			
28	Chiastolite	Andalusite (Crystals, when cut across exhibit cruciform			
29	Chloanthite	See Smaltine.			
30	Chloride, ammonium	See Sal-Ammoniac.			
31	— copper	See Atacamite.			
32	— lead	See Cotunnite, Cromfordite.			
33	— magnesium	See Carnallite.			
34	— mercury	See Calomel.			
35	— potassium	See Sylvine.			
36	— silver	See Horn Silver.			
37	— sodium	See Salt, Common.			
38	Chlorite	$4 H_2O.5 MgO.Al_2O_3.$ $3 SiO_2$ (Clinochlore)	III.rh.or V.	2·6—2·8	1·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
						1
						2
Greasy, shining	W., P. or R.	W.	Conch.	2 Intu- mesces	E.S.H$_2$O	3
Wax	R. and Br. R., tl.	R.	Am.	Inf.		4
Sy.	Y., G. Y.		Fibrous	3·5	Ins.	5
Ad. brilliant	Bl., Br.	W.—Br.	Sub. conch. or uneven	Inf.		6
						7
Vit. py.	W., tint pale B.	W.	Conch., very brittle	Fus.	Ins.	8
						9
	Br., R.	Gr., W.	Uneven, brittle	Inf.	Gelatinous SiO$_2$ with HCl.	10
Ad. vit.	C., W., Gr.		Conch.	Fus.	s.HNO$_3$	11
						12
Vit.	C., W., P.			3	Gelatinous SiO$_2$ with HCl.	13
Vit.	B.	W.	Conch.	Inf.	s.H$_2$O	14
Wax	W., Gr., Br., Y., R., P., G., B.	W.	Brittle	Inf.	s.HF and KOH	15
						16
Vit. py.	G.	W. G.	oP ; ∞P∞	Fus.	s.HNO$_3$	17
Vit.	Bright B.	?		Fus.	s.HCl.	18
	Bl. Br.	Br.				19
Res.	Grass G.	G.		Fus.		20
						21
	Cochineal R.					22
Earthy	W.	W.	Conch., earthy	Inf.	s.acids	23
						24
	B., G., G. Bl.			Inf.	Decomp. with liberation of SiO$_2$	25
Dull	Gr., Br., Bl.	Gr.	Conch.	Inf.	s.KOH and HF	26
						27
lozenge shaped or tessellated figures)						28
						29
						30
						31
						32
						33
						34
						35
						36
						37
Py. slightly greasy	G., Bl., Y., rose R.	W., G.	oP		Decomp.HCl. with floccu- lent SiO$_2$	38

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Chloritoid	$Al_2O_3.FeO.SiO_2.H_2O$	V.	3·45—3·6	6—6·5
2	Chlormagnesite	$MgCl_2$	IV.		
3	Chlorothionite	$(Cu,K_2)(SO_4.Cl_2)$	VI.		
4	Chondrodite	8 $MgO.3 SiO_2$, iron and fluorine present	V	3·1—3·25	6—6·5
5	Chromate, lead	See Crocoisite.			
6	Chrome, ochre	$SiO_2.Al_2O_3.Cr_2O_3.Fe_2O_3$	Am.		
7	— yellow	See Crocoisite.			
8	Chromic iron	See Chromite.			
9	Chromite	$Fe_2O_3.FeO$ with CrO and Cr_2O_3	I.	4·32—4·6	5·5
10	Chromium sulphide	Cr_2S_3. (From meteorites.)			
11	Chrysoberyl	$BeO.Al_2O_3$	IV.	3·5—3·8	8·5
12	Chrysocolla	$CuO.SiO_2.2 H_2O$	Am.	2—2·23	2—4
13	Chrysolite	2 $(Mg,Fe)O.SiO_2$	IV	3·3—3·5	6—7
14	Chrysoprase	SiO_2. Chalcedony, with NiO.	Am	2·64	7
15	Chrysotile	See Serpentine (fibrous variety)			
16	Cinnabar	HgS	III rh	8·99	2—2·5
17	Cinnamon stone	See Garnet, Lime-Alumina	I rh	3·5—3·6	7—7·5
18	Citrine	See Quarz. SiO_2			
19	Claudetite	As_2O_3	IV.		
20	Clausthalite	PbSe	I.	8·2—8·8	2·5—3
21	Clay ironstone	See Limonite (Limonite in nodular forms. Argillaceous)			
22	Clay	Variable.	Am. IV.rh.	2·4—2·6	1—2·5
23	Cleavelandite	Lamellar Albite			
24	Cleveite	Hydrated UO_3 contg. Y, Er, Ce, Th, A, He	I.	7·49	5·5
25	Clinkstone	See Phonolyte			
26	Clinochlore	See Chlorite.			
27	Clinoclase	See Aphanesite.			
28	Clintonite	10 $(Mg,Ca,Fe)O 5Al_2O_3$ 4 $SiO_2.3 H_2O$	V	3·1	4—5
29	Coal—Mineral	About 82·85% fixed C.	Am.	1·57—1·67	2—2·5
30	— brown	Less C than above, More O and H_2O	Am.	1·2—1·5	1—2
31	Cobalt	Does not occur native.			
32	— bloom	See Erythrine.			
33	— glance	See Smaltine.			
34	— vitriol	See Bieberite.			
35	Cobaltine	$CoAsS (CoS_2 + CoAs_2)$	I.	6—6·3	5·5
36	Coccolite	Augite.	Am.	3·25—3·3	5—6
37	Colemanite	2 $CaO.3 B_2O_3.5 H_2O$	V.	2·43	4—4·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility	Solubility	
Vit. wax	Bl. G., G.	W., G.	oP	d.fus.	Decomp H_2SO_4. gel SiO_2 with HCl	1
Vit.	W., C.	C.	Brittle			2
Vit.	Bright B.	W.		Inf.	E.S.H$_2$O	3
Vit. res.	W., Br., Y., R., tl.—stl.	W., Y., Gr.	Uneven	Inf	Gelatinous SiO_2 with HCl.	4
						5
Dull	Gr.	Gr.	Earthy			6
						7
						8
Submet	Iron or Br. Bl.	Dark Br.	Rough	Inf.	Ins.	9
	Bl.					10
Vit.	All shades of G.	C.	Conch., uneven	Inf.	Ins.	11
Enamel-like	B. G., sky or turquoise B.	W.	Conch., brittle or sectile	Inf.	s.acids	12
Vit.	P. G., tr; olive G., Br., tl or stl.	C.	Conch.	Inf.	Ins.	13
Vit.	Apple G.	G.	Splintery	Inf.	s.HF and KOH	14
						15
Ad.	R., Gr., Br.	Scarlet	Subconch., uneven	Volatilizes		16
Vit., res. or dull	Cinnamon or Y.	W.	Flat conch.	Inf.	Ins.	17
	Y. W.	Citron Y.				18
						19
Met.	Gr.	Gr.	$\infty O \infty$	Inf.	s.HNO$_3$	20
						21
Dull	Gr., W., Y., Br., R.		Pasty	Inf.	Ins.	22
						23
Dull	Bl.	Bl., Br.			s.HCl., PbCl$_2$ seps out	24
						25
						26
						27
Met.—py.	R.Br., Y. Br., Y.	Y.	oP	Inf.	s.HCl	28
Submet.	Bl.	Bl.	Conch.	Burns		29
Dull	Br., Bl.	Br.	Conch.	Burns		30
						31
						32
						33
						34
Met.	W. tinged R.	Gr. Bl.	Brittle	Fus.	s.hot HNO$_3$	35
Dull	W., G.	W.	Granular	Fus.	Ins.	36
Vit.	W., Y. W., C.	W.	$\infty \overset{.}{P} \infty$	Fus.	s.hot HCl.	37

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Colophonite	See Garnet, Iron—lime	Am.	3·44	7
2	Columbite	(Fe,Mn) (Nb,Ta)$_2O_6$	IV.	5·25—7·3	6
3	Connellite	$CuSO_4.CuCl_2$	III.	2·9—3·2	2—3
4	Copaline (Highgate Resin)	A Bitumen.			
5	Copiapite	$Fe_4S_3O_{18}+12 H_2O$	V.	2·1	2·5
6	Copper, Native	Cu	I.	8·8	2·5—3
7	— black	See Melaconite.			
8	— blue	See Covellite.			
9	— froth	Copper arsenate (43·9 % CuO)	IV	4·2	2·5—3
10	— glance	See Redruthite.			
11	— grey	See Tetrahedrite.			
12	— mica	See Chalcophyllite			
13	— nickel	See Kupfernickel.			
14	— pyrites	$Cu_2S.Fe_2S_3$	II. sph.	4·1—4·3	3·5—4
15	— red	See Cuprite.			
16	— silicate	See Dioptase, Chrysocolla.			
17	— vitriol	See Chalcanthite.			
18	Copperas	$FeSO_4.7 H_2O$	V.	1·83	2
19	Coprolites	Apatite of organic origin. (Supposed to be excrement of			
20	Coquimbite	$Fe_4S_2O_{12}.9 H_2O$	IV.	2—2·1	2—2·5
21	Cordierite	See Iolite.			
22	Corundum	Al_2O_3	III. rh.	3·90—4·16	9
23	Cossyrite	Amphibole, with Na_2TiO_3	VI.		
24	Cotunnite	$PbCl_2$ (74·5% Pb)	IV.	(Acicular crystals.)	
25	Covellite	CuS	III. rh. h.	4·59—4·6	1·5—2
26	Crocidolite	$(Fe,Na_2)_3Si_4O_{18}.$ $FeSiO_3$	V.	3·2	4
27	Crocoite (crocoisite)	$PbO.CrO_3$	V.	5·9—6·1	2·5—3
28	Cromfordite	$PbCl_2.PbCO_3$		6—6·31	2·75—3
29	Cronstedtite	Chlorite, containing Mn	III.	3·35	3
30	Crookesite	CuSe with 17·25% Th and a little Ag	I.		
31	Cryolite	$3 NaF.AlF_3$	V.	2·9—3	2·5—3
32	Cuprite	Cu_2O	I.	5·8—6·15	3·5—4
33	Cyanite	See Kyanite.			
34	Cyanosite	See Chalcanthite.			
35	Danaite	Mispickel with 6·5% Co	Other properties as for mispickel		
36	Danalite	2 (Mg,Fe)O.SiO$_2$ with Zn,Be,Fe & Mn	I.	3·42	5·5
37	Danburite	$CaO.B_2O_3.2 SiO_2$	IV.	2·95	7
38	Datolite	$2 CaO.B_2O_3.2 Si.O_2.$ H_2O	V	2·9—3	5—5·5

Lustre.	Colour	Streak.	Fracture	Fusibility.	Solubility.	
Res.	Dark R. Br.	P	Granular, coarse			1
Met. ad.	Br., Gr. Bl.	Bl., Br., R	∞P∞	Inf.	Ins.	2
Vit. ad.	Fine Bl	W	Conch		s.H$_2$O	3
Wax	Pale Y or Br.	Y		Burns		4
Py.	Y., Y. G.	Y.	∞P∞	Inf.	s.H$_2$O	5
Met	Copper R.	Met. R.		Fus. 2—3	s.HNO$_3$	6
						7
						8
Dull	Apple G	G.				9
						10
						11
						12
						13
Met.	Brass Y	G. Bl.	Conch., uneven	Fus.	s.HNO$_3$ with sepn. of S.	14
						15
						16
						17
Vit. glazy	G., Y. Br., W.	C.	C'ch., brittle	Fus.	s.H$_2$O	18
certain saurians, &c.)						19
Vit.	W., Y., Br., B.	W	Brittle	Inf.	s.H$_2$O	20
						21
Vit. or dull	W. Gr., Y., R., Br., B.	W.	Conch.	Inf.	Ins.	22
						23
	W.					24
Wax, dull	Dull B. Bl.	Gr., Bl.	oR	E. fus.	s.HNO$_3$ with sepn. of S.	25
Sy. Asbesti-form	Leek G. Y., Br., B.	B. Gr.	Fibrous	E. fus.	Ins.	26
Ad.—vit.	Hyacinth R., tl.	Orange	∞P	E. fus.	s.hot HCl with Sepn. of PbCl$_2$	27
Ad.	W. Gr., Y. tr. tl.	W.	Conch.		s.HNO$_3$ with loss of CO$_2$	28
Vit.	Bl.		oP			29
	Bl., Gr.	Gr.				30
Vit.	C., W. Gr.	C.	∞P, oP, P∞	1	s.H$_2$SO$_4$	31
Ad. sub. met.	R. (cochineal)	Br R.	Conch., uneven, brittle	Fus.	s.acids	32
						33
						34
						35
Vit. res.	Flesh R.—Gr.	Gr. P.		Inf.	Gelatinous SiO$_2$ with HCl.	36
Vit. oily	Y., W.	Y.	Uneven	3	Gelatinous SiO$_2$ with HCl.	37
Vit.	C., W., Gr. G., Y., R.	C. W.	Conch., uneven	2	Gelatinous SiO$_2$ with HCl.	38

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Dawsonite	$Al_2(CO_3)_3.Na_2CO_3.$ nH_2O			
2	Delessite	$4 (Mg,Fe)O.2(Al_2,Fe_2)$ $O_3.4 SiO_2.5 H_2O,$ rich in iron	Microcryst	$2\cdot7—2\cdot9$	$2—2\cdot5$
3	Derbyshire Spar	See Fluor Spar.			
4	Decloizite	$3 PbO.V_2O_5.Zn(OH)_2$	IV.	$5\cdot8—6\cdot25$	$3\cdot5$
5	Desmine	$(Ca,Na_2)O.Al_2O_3.$ $6 SiO_2+6 H_2O$	V.	$2\cdot1—2\cdot2$	$3\cdot5—4$
6	Deweylite	$3 MgO.H_2O.2 SiO_2+$ $20\% H_2O$	Am.	$1\cdot9—2\cdot25$	$2—3\cdot5$
7	Diallage	$(Mg,Fe)O.CaO.2SiO_2$ with some Al_2O_3	V.	$3\cdot2—3\cdot3$	4
8	Diallogite	See Rhodochrosite.			
9	Diamond	C.	I.	$3\cdot52$	10
10	Diaphorite	$5(Pb,Ag_2)S.2 Sb_2S_3$	IV.	As for Freieslebenite	
11	Diaspore	$Al_2O_3.H_2O$	IV.	$3\cdot5$	$6\cdot5—7$
12	Dichroite	See Iolite.			
13	Dickinsonite	$3(Mn,Fe)O.P_2O_5+$ CaF_2	IV.	$3\cdot4—3\cdot8$	$5—5\cdot5$
14	Dihydrite	See Pseudomalachite.			
15	Diopside	$MgO.CaO.2 SiO_2$	V.	$3\cdot3$	$5—6$
16	Dioptase	$CuO.SiO_2+H_2O$	III.rh.t.	$3\cdot2—3\cdot35$	5
17	Diorite	Rock. Hornblende and Felspar			
18	Diphanite	See Margarite.			
19	Disthene	See Kyanite.			
20	Dog-tooth spar	See Calcite.	III.rh.h.		
21	Dolerophanite	$CuSO_4.CuO$	V.	$3\cdot5—3\cdot7$	
22	Dolomite	$CaCO_3.MgCO_3$	III.rh.	$2\cdot8—2\cdot9$	$3\cdot5—4$
23	Domeykite	Cu_3As_2	I.	$7—7\cdot5$	$3—3\cdot5$
24	Dufrenoysite	$2 PbS.As_2S_3$	IV.	$5\cdot5—5\cdot7$	3
25	Dumortierite	$4 Al_2O_3.3 SiO_2$	IV.	$3\cdot3—3\cdot4$	7
26	Durangite	$2 NaF.Al_2O_3.As_2O_5$	V.	$3\cdot9—4\cdot1$	5
27	Dysanalyte	$(Ca,Ce,Fe)O.Nb_2O_5$	I.		
28	Dyscrasite	Ag_3Sb	IV.	$9\cdot4—9\cdot8$	$3—3\cdot5$
29	Earthy Cobalt	Wad(q.v.)with $0—40\%$ $CoO,CoS, CuO,$ Fe_2O_3,NiO	Am.		
30	Edingtonite	$BaO.Al_2O_3.3 SiO_2.$ $3 H_2O$	I.sph.h.	$2\cdot7$	$4—4\cdot5$
31	Eggonite	$CdO.SiO_2$	IV.		$4—5$
32	Ehlite	See Pseudomalachite.			
33	Elæolite	See Nepheline.			
34	Elastic Bitumen	See Bitumen, elastic			
35	Elaterite	See Bitumen, elastic.			
36	Electric Calamine	See Hemimorphite.			
37	Electrum	$Au_mAg_{n_1}(Ag>20\%)$	I.	$13—16$	$2\cdot5—3$

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility	
	C. W.					1
Vit.	G., Bl. G.	Gr. G.	Fibrous	d.fus.	Flocculent SiO_3 with HCl.	2
						3
	Bl., Br., Olive G.	Br.				4
Vit.	C., W., Y.	W.	$\infty \check{P} \bar\infty$	Fus.	Powdery SiO_2 with HCl.	5
Res.	W. tinge Y., Br., G., R.	W.	Very brittle			6
Py met.	Gr., G., Br., tr. ti.	W., Gr.	Brittle	5	Ins.	7
						8
Ad.	C., P., Y., B., Bl.		Conch.	Inf.	Ins.	9
						10
Sy. py.	C., Gr., Y.		$\infty P \bar\infty$	Inf.	s.H_2SO_4 after heating to red heat	11
						12
Res.	Oil G., olive G.	Gr. G.		E. fus.	s.HCl.	13
						14
Vit.	C., Gr., G.	C.	$\infty P87°$	3—4	Ins.	15
Vit.	Emerald G., tr. stl.	G.	Conch., uneven, brittle	Inf.	Gelatinous SiO_3 with HCl.	16
						17
						18
						19
						20
Vit.	B.	Br.	Brittle			21
Vit. py., dull	W., Y., Br., G.	W. Gr.	Conch. or uneven	Inf.	s.warm acids	22
Met.	W.—pinchbeck Br.	W.	Conch.	Fus.	s.HNO_3	23
						24
Met.	Gr., Gr. Bl.	R. Br.	oP	E. fus.		25
	B., Gr. B.			Inf.		25
Vit.	R., Y., Gr. Bl.	Y.	∞P	E. fus.	s.H_2SO_4	26
						27
Met.	Tin W.	W met.	oP, P$\bar\infty$	3·5 Sb volatilises	s.HNO_3	28
Dull	Bl., B. Bl.	Bl. res.	Earthy	Int.	s.HCl.	29
Vit.	Gr. W., P.		∞P	d. fus.	Gelatinous SiO_2 with HCl.	30
Sub. ad.	Tl., Gr. Br.		oP, P$\bar\infty$	Inf.		31
						32
						33
						34
						35
						36
Met.	Y., W.	Y., W., shining	Tough	Fus.	s.HNO_3 + HCl.	37

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Eleonorite	3 Fe₂O₃.2 P₂O₅.8 H₂O	V.		3—4
2	Eliasite	UO.U₂O₃.xH₂O		9·2—9·3	5·5
3	Elpasolite	3 KF.AlF₃ (Cryolite with K instead of Na)			
4	Elpidite	Na₂O.ZrO₂.6 SiO₂.3 H₂O			
5	Embolite	Ag(Cl,Br)	I.	5·79	1·5
6	Emerald	See Beryl (contains Cr.)			
7	— Brazilian	Tourmaline (q.v.)			
8	— Oriental	See Corundum.			
9	— Copper	See Dioptase.			
10	— Nickel	NiCO₃.6 H₂O	Am.	2·5—2·6	3—3·25
11	Emery	See Corundum.			8·5—9
12	Emeryllite	See Margarite.			
13	Emmonsite	FeTeO₃	V.	5	2
14	Emplectite	Cu₂S.Bi₂S₃	IV.	6·23—6·52	2·5
15	Enargite	6 CuS.As₂S₃	IV.	4·3—4·5	3
16	Endellionite	See Bournonite.			
17	Enstatite	MgO.SiO₂ or (MgO,FeO)SiO₂	IV.	3·1—3·3	5·5
18	Eosphorite	(Fe,Al,Mn)₂O₃.P₂O₅. 5 H₂O.Mn essential, Fe low percentage	IV.	3·1—3·5	5·5—6
19	Epidote	4 CaO.3(Al,Fe)₂O₃. 6 SiO₂.H₂O	V.	3·2—3·5	6—7
20	Epistilbite	CaO.Al₂O₃.6 SiO₂. 5 H₂O	V.	2·24—2·36	3·5—4
21	Epsom Salt	MgSO₄.7 H₂O	IV.		
22	Erinite	2 CuO.As₂O₃.4 H₂O	Deposit	4·04	4·5—5
23	Erubescite	See Bornite.			
24	Erythrine	3 CoO.As₂O₅.8 H₂O	V.	2·95	1·5—2·5
25	Essonite	See Garnet, Lime-alumina.			
26	Ettringite	CaSO₄.Al₂(SO₄)₃	III.		3—3·5
27	Eucairite	Ag₂Se.Cu₂Se		7—9	1
28	Euchroite	CuO(48%)As₂O₅(33%)	IV.	3·39	3·75
29	Eudeiolite	(Ca,Ce,Fe,Hg,Na)O. (Nb,Ti,Th)O₃.H₂O	I.	3·44	4
30	Eudialite	NaCl.6 Na₂O.6(Fe, Ca)O.20(Si,Zr)O₂	III.rh.h.	2·8—2·9	5—5·5
31	Euclase	2 BeO.Al₂O₃.2 SiO₂. H₂O	V.	3·1	7·5
32	Eucrasite	Altered Thorite	Am.	4·39	4·5—5
33	Eulytine	2 Bi₂O₃.3 SiO₂	I.tetr.h.	6·1	4·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit. py.	R., R. Br.	Y	$\infty P \overline{\infty}$	E. fus.	E.s.HCl.	1
Res.	R. Br., Bl.					2
						3
						4
Ad.	G., Bright G.	Y. G.	Conch.	E. fus.	d.s.HCl.	5
	Bright G.					6
	Tr. G.					7
	Tr. G.					8
						9
Vit.	Emerald G., tr. tl.	Pale G.	Brittle	Inf.	s.dil.HCl.	10
	Gr. Bl.					11
						12
	Y. G.					13
Met.	Gr. W.	Bl.	$\infty P \overline{\infty}$	E. fus.	s.HNO$_3$	14
Met.	Gr. Bl.	Bl.	∞P	E. fus.	s.HNO$_3$ with sepn. of S.	15
						16
Vit. py.	Gr., G., Br., Y., C., stl.—op.	W Gr.	$\infty P, \infty P \overline{\infty}$	6	Ins.	17
Rather wax	Rose R.	P				18
Vit.	G., Y G., Br G., Bl.G.	Gr.	o P, $\infty P \overline{\infty}$	3·5	After heating to red heat gel. SiO$_2$ HCl.	19
Py., vit.	C., W., W. B.		$\infty P \overline{\infty}$	Fus.	Decomp hot HCl with formn. of powdery SiO$_2$	20
Vit.—earthy	W.	W		Gives off	water s. H$_2$O	21
Dull	Emerald G.	G.		Fus.		22
						23
Py. ad. vit., dull	Peach R., crimson, G. or Gr	As colour but paler, Lavender B.	Earthy	Fus.	s.HCl.	24
						25
Vit.	W	W	Powdery			26
Met.	Silver W.— lead Gr.	Gr.	Tough			27
Wax —dull	Bright G.	G.	Brittle	Fus.	s.HNO$_3$	28
Vit	Bl Br.	?	Conch brittle			29
Vit.	R., P., Br		oR	E fus	Gelatinous SiO$_2$ with HCl.	30
Vit.	G., W., C., B., tr	W	$\infty P \overline{\infty}$	5·5	Ins.	31
Waxy	Bl., Br	Br	Uneven. conch	d fus	s H$_2$SO$_4$	32
Ad.	Br., Y., Gr	W G. Gr.	Conch	E. fus.	Gelatinous SiO$_4$ with HCl.	33

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Euphyllite	$CaO.K_2O.3\ Na_2O.$ $14\ Al_2O_3.23\ SiO_2.$ $9\ H_2O$	Schistose	2·5—3	2—2·5
2	Eusynchite	$(Pb,Cu)O.V_2O_5$			
3	Euxenite	$(Y,Ce,Er)_2Ti_6O_{15},$ $(Y,Er,Ce)_2Nb_6O_{18},$ $Fe(UO)Ti_6O_{15},$ $Fe(UO)Nb_6O_{18},$ containing Ge	IV.	4·6—5	6·5
4	Fahlerz	See Tetrahedrite.			
5	Fahlunite	$2\ FeO.SiO_2.Al_2O_3.$ $2\ SiO_2.H_2O$	III.	2·7	1·5—2
6	Fairfieldite	$(Mg,Ca)_3(PO_4)_2.x\ H_2O$	VI.		3·5
7	Faujasite	$(Na_2,Ca)O.Al_2O_3.$ $5\ SiO_2.10\ H_2O$	I.	1·9	5—5·5
8	Fayalite	$2\ FeO.SiO_2$	IV.	3·9—4·1	6
9	Feather ore	See Jamesonite.			
10	Felspar, Potash	$K_2O.Al_2O_3.6\ SiO_2$ (See also Microcline)	V or VI.	2·55—2·58	6
11	—, Soda	See Albite.			
12	Felsite	Orthoclase. (Has the texture of flint or jasper.)			
13	Ferberite	$FeWO_4$	V.	6·7—6·8	4—4·5
14	Fergusonite	$Y(Nb,Ta)O_4$	II. pyr. h.	5·8—5·9	5·5—6
15	Ferrotellurite	$FeTeO_4$			
16	Fibrolite	$Al_2O_3.SiO_2$	IV.	3·2—3·3	6—7
17	Fichtelite	$C_{18}H_{32}$	V.		
18	Fiorite	SiO_2	Globular		
19	Fischerite	$2\ Al_2O_3.P_2O_5.+8\ H_2O$	IV.	2·5	5
20	Flint	SiO_2, compact	III.	2·6—2·64	7
21	Float Stone	Porous opal			
22	Flos ferri	$CaCO_3$ with iron (Coralloidal).			
23	Fluellite	$AlFe_3.H_2O$	IV.	2·17	
24	Fluocerite	$(Ce,La,Di)_2OF_4$; Cerium ore 82%	III.	5·7—5·9	4
25	Fluorite	CaF_2	I.	3—3·25	4
26	Fluor Spar	See Fluorite.			
27	Foliated Tellurium	See Nagyagite.			
28	Fontainebleau Limestone	$CaCO_3$ with up to 85% SiO_2	III.rh.		
29	Forsterite	$2\ MgO.SiO_2$	IV.	3·2—3·3	7
30	Fowlerite	$(Mn,Fe,Ca,Zn,Mg)O.$ SiO_2	V.	3·3—3·6	4—5
31	Franklinite	$(Fe,Zn,Mn)O.Fe_2O_3$	I.	5—5·1	6—6·5
32	Freibergite	Argentiferous Tetrahedrite (q.v.)			
33	Freislebenite	$5(Pb,Ag_2)S.2\ Sb_2S_3$	V.	6·2—6·4	2—2·5
34	French Chalk	Talc (q.v.).			
35	Freyalite	$ThSiO_4$	Am.	4—4·2	
36	Friedelite	Mn_5SiO_4			
37	Fuchsite	Muscovite contg. Cr.	V.	2·6—2·8	
38	Fuller's Earth	$2\ Al_2O_3.3\ SiO_2+aq$	Am.		1—1·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Py.	C., W.	W.	Brittle	Fus.		1
	Olive G.; Bl.G.	G.				2
Greasy	Br.Bl.	R.Br.	Conch.	Inf.	Ins.	3
						4
Py.	Gr.G.—Bl.	G.	Brittle	Fus.	Ins.	5
	W., Y.			D. fus.		6
Vit.—ad.	C., W.		Am.	E. fus.	Gelatinous SiO_2 with HCl	7
Fatty	G.Bl.—Bl.	Br.		E. fus.	Gelatinous SiO_2 with HCl	8
						9
Vit.	W., P., Gr., G., B.	W.Gr.	Conch. splintery	5	Ins.	10
				5	Ins.	11
						12
Vit.	Bl.	Bl.Br.				13
Met. fatty	Bl., Bl.Br.	Br.	Incomplete conch.	Inf.		14
Vit.	Y., G.	W.				15
Vit.—py.	Hair Br.—Gr.	Gr.Br.	Easy	Inf.		16
Py.	W.			46°	$s.(C_2H_5)_2O$	17
Py.	Py.W.	W.				18
Vit.	G.	G.W.			$s.H_2SO_4$	19
	Smoky Gr., Br., Bl.		Splintery	Inf.		20
						21
						22
						23
Wax	P., G.	?	Uneven			24
Vit. glimmering	C., W., G., Y., purple	W.	Conch. uneven	E. fus.	$s.H_2SO$	25
						26
						27
						28
Vit.	C., W., Y.	?	$\infty P \infty$	Inf.	Gelatinous SiO_2 with HCl	29
Vit.	C., P., Gr., Y.			3		30
Met.	Bl.	Br.	Conch. uneven	Inf.	s.hot HCl	31
						32
Met.	Bl.Gr.	Gr.	Uneven	E. fus.	$s.HNO_3$ with sepn.of $PbSO_4$	33
Py.	Milk W.					34
	Br.	Y.Gr.		Inf.	s.HCl	35
Vit.—res.	Rose R.	P.				36
	G.		oP			37
Earthy	G.Br., G.Gr.	W. shining	Earthy	Fus.		38

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Gadolinite	$FeO.2 SiO_2.2 BeO.$ $(Y,Ce,La,Di)_2O_3$	V.	4·2—4·35	6·5—7
2	Gahnite	$(Zn,Fe)O.Al_2O_3$	I.	4—4·6	7·5—8
3	Galena	PbS	I.	7·2—7·7	2·5—2·7
4	Galmei	See Hemimorphite.			
5	Ganomatite	$Fe_2O_3.As_2O_3.Sb_2O_4.$ $x H_2O$	Am.	2—2·3	Soft
6	Garnet, Lime-alumina	$6 CaO.3 SiO_2 +$ $2 Al_2O_3.3 SiO_2$	I.	3·4—3·7	6·5—7
7	—, Magnesia-alumina	$6 MgO.3 SiO_2 +$ $2 Al_2O_3.3 SiO_2$	I.	3·69—3·8	7·5
8	—, Iron-alumina	See Almandine.	I.		
9	—, Manganese-alumina	$6 MnO.3 SiO_2 +$ $2 Al_2O_3.3 SiO_2$	I.	3·7—4·4	7—7·5
10	—, Iron-lime	$6 CaO.3 SiO_2 +$ $2 Fe_2O_3.3 SiO_2$	I.	3·44	7+
11	—, Lime-chrome	$6 CaO.3 SiO_2 +$ $2 Cr_2O_3.3 SiO_2$	I.	3·4	7·5
12	Garnierite	$(Ni,Mg)O.SiO_2 +$ $x H_2O$	Am.	2·3—2·8	2·5
13	Gaylussite	$Na_2CO_3.CaCO_3.5 H_2O$	V.	1·9	2·5
14	Gehlenite	$3 CaO.Al_2O_3.2 SiO_2$	II.	2·9—3	5·5—6
15	Genthite	$(Ni,Mg)O.SiO_2.x H_2O$	Am.	2·3—2·5	2·5
16	Geokronite	$5 PbS.Sb_2S_3$	IV.	6·4—6·5	2—2·5
17	Gerhardtite	$Cu(NO_3)_2$	IV.	3·2—3·7	3·5—4
18	Gersdorffite	$NiS_2 + NiAs_2$		5·6—5·9	5·5
19	Gibbsite	See Hydrargillite.			
20	Gismondine	$CaO.Al_2O_3.4 SiO_2.$ $4 H_2O$	V.	2·4	5—5·5
21	Glassy Felspar	See Sanidine.			
22	Glauberite	$CaSO_4.Na_2SO_4$	V.	2·7—2·8	2·5—3·
23	Glauber salt	$Na_2SO_4.10 H_2O$	V.	1·48	1·5—2
24	Glaucodote	$(Fe,Co)S_2,(Fe,Co)As_2$	IV.	5·9—6	5
25	Glauconite	Al,Fe,K,Mg,Ca silicate	Am.	2·2—2·4	2
26	Glaucophane	$Na_2O.Al_2O_3.4 SiO_2.$ $(Fe,Mg,Ca)O.SiO_2$	V.	3—3·1	6—6·5
27	Gmelinite	$(Na_2,Ca)O.Al_2O_3.3SiO_2$ $6 H_2O$	III.rh.h.	2—2·1	4·5
28	Goethite	$FeO.OH$	IV.	4—4·3	5—5·5
29	Gold	Au	I.	12—20	2·5—3
30	Gold Amalgam	Ag, Au and Hg $(Au = 40\%)$	Am.	12—18	
31	Goslarite	$ZnSO_4.7 H_2O$	III.rh.	4—4·1	5—5·5
32	Göthite	$Fe_2O_3.H_2O$	IV.	4—4·4	5—5·5
33	Grammatite	See Tremolite.			
34	Graphic Tellurium	$(Au,Ag)Te_2$	V.	5·73—8·28	1·5—2
35	Graphite	C (often with up to 5% of SiO_2, &c.)	III.	2	1—2

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit.	Bl.	G.Gr.	Conch.	Inf.	Gelatinous SiO_2 with HCl	1
Vit. fatty	G., B.	W.Gr.	Earthy	Inf.	Ins. ac. and alk.	2
Met.	Lead Gr.	Lead Gr.	Flat, even	Fus.	s.HNO_3 with sepn. of S. and $PbSO_4$	3
						4
Vit. fatty	Y.G., R., Br.	?				5
Vit.	W., Y., P., pale G.	W.	Flat, conch.	3	Gel. SiO_2 with HCl after fusion	6
Vit.	Crimson or mulberry	P.	Conch.	3·5	No gel. SiO_2 with HCl after fusion	7
						8
Vit.	Hyacinth, Br.R.	W.	Conch., imperfect	Fus.	Decomp. HCl after fusion	9
Vit.	Br.G., Y.G., Br.	W	Conch.			10
Vit.	Emerald G.	G.W.	Conch.	Inf.	Ins.	11
Dull	Apple G.—W.	G.	Earthy	Inf.	Decomp. HCl	12
Vit.	C., W.		Conch.	3	Partly s. H_2O	13
Fatty	G., Gr.G., Y.		Uneven	D. fus.	Gelatinous SiO_2 with HCl	14
Dull	Pale, apple G.	G.	Earthy	Inf.	Ins.	15
Met.	Gr., Bl.	Gr.	∞P	E. fus. 1·5		16
	Dark G.				Ins. H_2O	17
Met.	W.—Gr.	Gr.	Flat	E. fus. S. & As. volatilise	s.HNO_3 with sepn. of S.& As_2O_3	18
						19
Vit.	W.Gr.		Uneven	3	Gelatinous SiO_2 with HCl	20
						21
Vit.	C., Y., Gr.	C.	oP	1·5	s. H_2O	22
Vit.	C.	C.	∞P∞̄	E. fus.	s. H_2O	23
Met.	W.	Gr.Bl.	oP	E. fus.	s. HNO_3 with sepn. of S.	24
Dull	Olive G., Y., Gr., Bl.G.	G.W.	Earthy	4	Ins.	25
Py. vit.	B.Gr., B.,B.Bl.	B.Gr.	∞P 124°	E. fus.	Ins.	26
Vit.	Y.W., P., R.		∞P	Fus.	Gelatinous SiO_2 with HCl	27
Ad.	R., Br., Bi.	Y.Br.	Conch.	Inf.	E.s. HCl	28
Met.	Y.	Y.	Tough	Fus.	s. Aqua-regia	29
Met.	W. or Y.	W.	Crumbles easily	Fus.		30
Vit.	C., Y.	C.	Conch.		s. H_2O	31
Ad.	Y., R., Bl.Br., tl.	Ochre Y.	Conch.	Inf.	s. HCl	32
						33
Met.	Steel Gr.—W., Y.	Gr.—W.	Uneven	Fus.		
Met.	Iron Bl.	Bl. shining	Sectile	Burns	Ins.	

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Gray Antimony	See Antimonite.			
2	— Copper	See Tetrahedrite.			
3	Greenockite	CdS	III.(h.)	4·8—4·9	3—3·5
4	Greenovite	Titanite contg. Mn	V.		
5	Greenstone	Oligoclase and Hornblende		2·66—3·0	
6	Green Vitriol	See Copperas.			
7	Grossularite	See Garnet, Lime-Alumina.			
8	Grünauite	Bi, Ni sulphides	III.	5·13	4·5
9	Guanajuatite	Bi_2Se_3			
10	Guano	Chiefly Ca_3PO_4, Aq	(Of organic origin.)		
11	Guarinite	$CaO.TiSiO_4$	IV.	3·4—3·56	5—5·5
12	Guayacanite	See Enargite.			
13	Guitermannite	$PbS.PbAs_2O_4$	I.	5·94	
14	Gummite	$(Pb,Ca,Ba)O.3\ UO_3.$ $SiO_3.5\ H_2O$ containing Ra.	Am.	3·9—4·5	2·5—3
15	Gymnite, Nickel	See Genthite.			
16	Gypsum	$CaSO_4.2\ H_2O$	V.	2·3	1·5—2
17	Hair salt	See Epsom salt.			
18	Haidingerite	$2\ CaO.As_2O_5.3\ H_2O$	IV.	2·8	2—2·5
19	Halite	See Rock-salt.			
20	Halotrichite	$Fe_2(SO_4)_3.(NH_4)_2SO_4.$ $24\ H_2O$	I.	1·71	
21	Hamartite	See Bastnäsite.			
22	Hanksite	$Na_2SO_4.Na_2CO_3$	III.		3—3·5
23	Harmotome	$(K_2,Ba)O.Al_2O_3.$ $5\ SiO_2.5\ H_2O$	V.	2·3—2·5	4—4·5
24	Hatchettine	C_nH_{2n+2}	Am.		·5—1
25	Hatchettolite	$U(NbTa)O_3.H_2O$	I.	4·76—4·84	5·5
26	Hauchecornite	$(Ni,Co)_7(S,Bi,Sb)_6$	II.	6·4	5
27	Hauerite	MnS_2	I.pent.h.	3·46·	4
28	Hausmannite	Mn_3O_4	II.	4·72	5—5·5
29	Haüyine	$5\ (Na_2,Ca)O.3\ Al_2O_3.$ $6\ SiO_2.2\ SO_3$	I.	2·4—2·5	5·5—6
30	Heavy Spar	See Barytes.			
31	Hedenbergite	$CaO.FeO.2\ SiO_2$	V.	3·47	
32	Hedyphane	$3\ (3\ PbO.As_2O_5)+$ $PbCl_2$ with much CaO	Am.	5·4—5·5	3·5—4
33	Heliotrope	SiO_2 microcrystalline		2·6—2·64	7
34	Helvite	$3\ SiO_2.6\ (Mn,Be,Fe)O.$ $(Mn,Fe)S$	I.tetr.	3·1—3·3	6—6·5
35	Hematite, Brown	See Limonite.			
36	—, Red	Fe_2O_3	III.rh. or Reniform	4·5—5·3	5·5—6·5
37	Hemimorphite*	$2\ ZnO.SiO_2.H_2O$	IV.	3·16—3·49	4·5—5
38	Hercynite	$FeO.Al_2O_3$	I.	3·91—3·95	7·5—8
39	Herderite	$Be(OH,F).CaPO_4$	IV.	3	5
40	Hessite	Ag_2Te	I.	8·3—9	2·5—3
41	Hjelmite	(Ca,Fe,Mn) tantalate	IV.	5·82	5

* Hemimorphite is taken as the English name. This is the Calamine of Dana.

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
						1
						2
Ad or Wax	Honey, citron, or Or.Y.	Or.Y.— BrickR.	∞ P	Inf.	s. HCl	3
	Rose R.	P.				4
	Gr.W.—G.W., G —Bl		Very tough			5
						6
						7
Met.	Gr.—W., Y	W.	Brittle	Fus.	s. HNO_3	8
Met.	Y., P., W.		Friable			9
						10
Ad.—res.	Br., Gr., Bl.	C.	Conch.	Fus.	Partly s. HCl	11
						12
						13
Fatty	R.Y., R.Br., P.	Y.	Conch., uneven			14
						15
Py.sy., ad. vit.	C., W., Gr., R., Br.	W.	Sectile	Inf.	s. HCl and 400-500 parts H_2O	16
						17
Vit.	C.W.	C.	$\infty P\bar{\infty}$	E. fus.	s. HNO_3	18
						19
	Violet			Loses H_2O at 230°	s. H_2O	20
						21
Vit.	C., W., P., Y.	C.	Flat	Fus.	s. H_2O	22
Vit.	W., Y., Gr., etc.	W.		Fus.	s. HCl	23
Wax	Y W —G.Y.	W.		Burns	s. Ether	24
Vit. fatty	R.Br., Bl.Br.	Br.	Conch.	D. fus.	Decomp. H_2SO_4	25
Met.	Y.	Gr.Bl.	Conch.	E. fus.	s. HNO_3 with sepn. of S.	26
Res.	R.Br., Br.Bl.	Br.P.	$\infty O \infty$	D. fus.	s. HCl with sepn. of S.	27
Sub. met.	Br.Bl.	Chestnut Br.	Uneven	Inf.	s. HCl	28
Vit. greasy	B., G.B.	C.	∞O	3·5	Gelatinous SiO_2 with HCl	29
						30
Vit.	Bl., Bl.G.	Gr.G.	∞P	Fus.	Decomp. HCl	31
Ad.	W.	W.	Brittle	Fus.		32
	G.with R.spots		Splintery	Inf.	s. HF	33
Vit. res.	Y., Br., G.		Uneven	E. fus.	Gelatinous SiO_2 with HCl	34
						35
Met. highly splendent	Iron Gr., Bl., R.	R.	Sub. conch. or uneven	Inf.	s. HCl	36
Vit. ad. py.	W., Y.Br., G., B.	W.	Uneven, brittle	Almost inf.	Gelatinous SiO_2 with ac.	37
Vit. dull	Bl.Gr.	Gr.G.		Inf.	Ins.	38
Vit.	Y., G.W.	C., W.	Conch.	Fus.	s. HCl	39
Met.	W.Gr.	Shining	Conch. even	E. fus.	s. hot HNO_3	40
Met	Bl.	Bl.Gr.				41

	Name.	Composition.	Cryst System.	Specific Gravity.	Hardness.
1	Heulandite	$Al_2O_3.3\ SiO_2 + CaO.$ $3\ SiO_2, 5\ H_2O$	V.	2·2	3·5—4
2	Hiddenite	See Spodumene. (Rivals Emerald as a gem.)			
3	Highgate Resin	See Copaline.			
4	Hisingerite	$2\ Fe_2O_3.7\ H_2O.3\ SiO_2$	Am.	3·045	3
5	Homilite	$FeO.2\ CaO.B_2O_3.2SiO_2$	V.	3·28	5·5
6	Hopeite	$Zn_3PO_4.x\ H_2O$	IV.		
7	Hornblende	$3\ (Mg,Fe)O.CaO.4SiO_2$	V.	3·1—3·3	5—6
8	Horn Lead	See Cromfordite.			
9	— Silver	$AgCl$	I.	5·5	1—1·5
10	— Stone	See Flint.			
11	Horse Flesh Ore	See Bornite.			
12	Huantajayite	$(Na,Ag)Cl$	I.		
13	Hübnerite	$MnWO_4$	V.	7·17	
14	Humboldtilite	See Melilite.			
15	Humite	See Chondrodite.			
16	Huntilite	Ag_3As	Am.	7·47	2·5—3·5
17	Hureaulite	$5\ (Mn,Fe)O.2\ P_2O_5.$ $5\ H_2O$	V.	3·2	3·5
18	Hyacinth	See Zircon.			
19	Hyalite	See Opal.			
20	Hyalophane	$BaO.K_2O.2\ Al_2O_3.$ $8\ SiO_2$	V.	2·8—2·9	
21	Hydrargillite	$Al(OH)_3$	III.	2·3—2·4	2·5—3·5
22	Hydraulic Limestone	$CaCO_3$ (impure).			
23	Hydrocyanite	$CuSO_4$	IV.	2·4—3·0	
24	Hydromagnesite	$2\ MgCO_3.Mg[CO_2.$ $(OH)_2]3\ H_2O$	V.	2·15	1·5—2
25	Hydronepheline	$2\ Na_2O.3\ Al_2O_3.$ $6\ SiO_2.7\ H_2O$	III.	2·25	5
26	Hydrophane	See Opal.			
27	Hydrous Silica	See Opal.			
28	Hydrozincite	$ZnCO_3.2\ Zn(OH)_2$		3·58—3·8	3·5
29	Hypersthene	$(Fe,Mg)O.SiO_2$	IV.	3·3	5—6
30	Ice	H_2O	III.rh.h.	0·9145	1·5
31	Iceland Spar	See Calcite.			
32	Ice Stone	See Cryolite.			
33	Idocrase	$Ca_6[Al(OH,F)]Al_2$ $(SiO_4)_5$	II.	3·34—3·45	6·5
34	Idrialite	Resin with HgS	Am.	1·4—1·6	1—1·5
35	Ilesite	$MnSO_4.(Zn,Fe)SO_4.$ H_2O	IV.		
36	Ilmenite	$FeO.TiO_2$	III.rh.t.	4·5—5·1	5—6
37	Ilvaite	$(Ca,Fe)O.Fe_2O_3.2SiO_2$	IV.	3·7—4·2	5·5—6
38	Indicolite	Tourmaline (q.v.)			
39	Infusorial Earth	See Tripolite.			
40	Iodide of Mercury	HgI_2	Am		
41	— — Silver	AgI	III.	5·5—5·7	1—1·5
42	Iodobromite	$Ag(Cl,Br,I)$	I.		
43	Iodyrite	AgI (See iodide of silver).			
44	Iolite	$4\ (Mg,Fe)O.4\ Al_2O_3.$ $10\ SiO_2.H_2O$	IV	2·6—2·7	7—7·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit. py.	C.W.R.Br.	W.	Conch., brittle	Fus.	s. ac.	1
	Emerald G.					2
						3
Greasy—vit.	Bl.—Br.Bl.	Y.Br.	Earthy	Inf.		4
Wax. vit.	Bl., Bl.Br.	Gr.Br.		E. fus.	E.s. HCl	5
Res.	Gr.W.	W.			s. HCl	6
Vit.	Bl., Bl.G., Bl.Gr.	G.Gr.	∞P 124°	E. fus.		7
						8
Res. ad.	C., Gr., G., Bl.	Shining	Sectile	Fus. gives Ag	s. NH_4OH	9
						10
						11
	C.			Fus.	H_2O decomposes it	12
Vit.	Br.Bl., R.tr.	R.Br.	∞ P ∞	Fus.	s. HCl	13
						14
						15
Met.	Gr.—Bl.	Gr.	Brittle	Fus.	s. HNO_3	16
Greasy	R.,—Br. Or.	Y.Br.	Conch., uneven	E. fus.	E.s. HNO_3	17
	R.tr.					18
						19
						20
Py.	W., C., Gr.			Inf.	d.s. hot HCl	21
						22
Vit.	G., Br., B.	W.	Conch.	Inf.	s. H_2O	23
Dull	W., Gr.		Earthy	Inf.	s. HCl	24
Vit.	C., W., Gr.		Uneven	2	Gelatinous SiO_2 with HCl	25
	W.Gr.					26
						27
Dull	W.Y.			Inf.	s. HCl, HNO_3	28
Py. met.	Br.G., Gr., G.Bl., R.	Gr., Br.Gr.	Uneven	Fus.	Ins.	29
Vit.	C., W., B.	C.	Conch.	0° C.		30
						31
						32
Vit. res.	Br., G., Y., Str.Stl.	W.	Sub. conch.	Fus. 3	Gelatinous SiO_2 with HCl	33
Res.	Gr., Br., R.	R.Br.,Bl.	Flaky	300°	s. hot H_2SO_4	34
	W., Y.	W.			s. H_2O	35
Met.	Gr.Bl.	Bl.	Conch.	6	d.s. HCl with sepn. of TiO_2	36
Vit.	Bl.—Gr.	Gr.	Conch.	Fus.		37
	B., B.Bl.					38
						39
Dull	R.Br.	R.	Earthy	Fus.		40
Ad. greasy	Gr., Y.		oP	E. fus.	s. NH_4OH	41
Res. ad.	Y.	Y.		Fus.	s. NH_4OH	42
						43
Vit.	B., Gr.B., Y.	C.		D. fus. 5	Ins.	44

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Iridium	Ir(Pt,Fe)	I.	22·6—22·8	6—7
2	Iridosmine	IrOs(Pt,Rh,Ru,&c.)	III.rh.h.	19·3—21·0	6—7
3	Iron, Magnetic	See Magnetite.			
4	— , Native	Fe	I.	7·3—7·8	4·5
5	— Pyrites	FeS₂	I.	4·8—5·2	6—6·5
6	— Sinter	Fe₂O₃.As₂O₅.aq	Am.	3·1—3·3	3·5—4
7	— Titanic	See Ilmenite.			
8	Ironstone, Clay	See Limonite (Nodular form).			
9	Iserine	See Ilmenite.			
10	Jade	See Tremolite.			
11	Jamesonite	2 PbS.Sb₂S₃	IV.	5·5—5·7	
12	Jargoon	See Zircon.			
13	Jasper	Impure SiO₂			
14	Jet	Like cannel coal	Am.		2—3
15	Johannite	See Uranvitriol.			
16	Kainite	KCl,MgSO₄,3 H₂O	V.	2·13	2
17	Kakoxene	2 Fe₂O₃.P₂O₅.12 H₂O	V. or VI.	2·3—2·4	3—3·5
18	Kalaite	See Turquois (contains Cu and Fe).			
19	Kalinite	K₂SO₄.Al₂(SO₄)₃. 24 H₂O	I.pent.h.	1·75	2—2·5
20	Kampylite	3 (3 PbO.As₂O₅)PbCl₂	(Barrel - shaped crystals of		
21	Kaneite	MnAs₂	I.	5·55	
22	Kaolin	Al₂O₃.2 H₂O.2 SiO₂	V.	2·2—2·6	1
23	Karpholite	(Mn,Fe)O.(Fe,Al)₂O₃. SiO₂.2 H₂O	V.	2·9	5
24	Katapleïte	(Na₂,Ca).ZrO₃. 3 SiO₂.2 H₂O	V. and III. (at 140°)	2·8	6
25	Keilhauite	Sphene with 9·6% Y.		3·69	6·5
26	Kermesite	2 Sb₂S₃.Sb₂O₃	IV.		
27	Kidney Ore	See Hematite, Red.			
28	Kieselguhr (Diatom Mud.)	Siliceous remains of diatoms	Am.		
29	Kieserite	MgSO₄.H₂O	V.	2·5—2·6	3
30	Koppite	(Ca,Ce,Fe,Hg,Na₂)O. NbO₂.H₂O	I.	4·45—4·56	
31	Krennerite	(Au,Ag)Te₂	IV.	8·35	2·5—3
32	Krokydolite	Na₂O.Fe₂O₃.4 SiO₂. FeO.SiO₂	V.	3·2.	4
33	Kupfernickel	NiAs	III.	7·3—7·6	5—5·5
34	Kyanite	Al₂O₃.SiO₂	VI.	3·6—3·7	5—7
35	Labradorite	Ab₁An₁—Ab₁An₃*	VI.	2·67—2·76	6
36	Lanarkite	PbSO₄.PbCO₃	V.	6·3—7	2—2·5
37	Langite	CuSO₄ aq	IV.	3·48—3·5	4
38	Lanthanite	La₂(CO₃)₃.9 H₂O	IV.	2·6—2·7	2
39	Lapis Lazuli	Near Haüyine	I.	2·38—2·45	5—5·5
40	Laumonite	CaO.Al₂O₃.4 SiO₂. 2 H₂O	V	2·3	3·5
41	Lawsonite	CaO.Al₂O₃.2 SiO₂. 2 H₂O	IV	3·1	8·5

*Ab=Albite ; An=Anorthite.

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Met.	W.Gr.	Gr.	∞ O ∞	Inf.	Ins.	1
Met.	W.	Gr.	oP.	Inf.	Ins.	2
						3
Met.	Gr.Bl.	Gr.	Hackly	Fus	s. ac.	4
Met.	Y. (Brass)	Br.Bl.	Brittle	Gives off S.		5
Vit.—sub. ad.	P. leek G. or liver Br.	Br.	Friable			6
						7
						8
						9
						10
	Lead Gr.		Fibrous			11
	C. & smoky-tinted					12
	R., Br., Y., op.					13
Splendent	Bl.	Bl.	Conch.	Burns		14
						15
Vit.	C., Gr., Y.		∞ P ∞		s. H_2O	16
Sy.	Y.	Y.	Fibrous	Fus.	s. HCl	17
						18
Vit.	C.	C.		E. fus.	E.s. H_2O	19
	Br.Y.					20
Met. (Mimetite.)	Gr.W.	Gr.		Gives off As_2O_3		21
Dull	W.	W.	Earthy	Inf.	s.hot H_2SO_4 with sepn. of SiO_2	22
Sy.	Y., G.Y.	Y.	Fibrous	3·5	Ins.	23
Vit.	Y., Y.Br., P., Gr.B., V_1		∞P.	E. fus.	Gelatinous SiO_2 with HCl	24
Res.—dull	Br.Bl.	Br.Bl.	Powders	E. fus.		25
Ad.	R.	R.	Conch	E. fus.	s. HNO_3	26
						27
Dull	W.Y.		Earthy	Inf.	s. HF, KOH	28
Vit.	W., Y., Gr.	W.	Conch.	E. fus.	s. H_2O	29
Vit.	Br.	Y.				30
Met.	Y.W.	Shining	oP.	Decrepitates	Decomp. HNO_3	31
Sy.	B.G.	B.Gr.	Fibrous	E. fus.	Ins.	32
Met.	Copper R., pale	Br.Bl.	Uneven	Fus.	s. Aqua-regia	33
Py.	W., B.	W.	Brittle	Inf.	s. hot HCl	34
Vit. py. or sub. res.	Gr., Br., G., R., B.	C., W.	Uneven, splintery	Fus.		35
Py, greasy	W., Y., Gr., G	W.	oP.	Fus.	Decomp.HNO_3	36
Vit.	B., G.	W.	Conch.	Fus.	s. H_2O	37
Dull, py.	W., Y., P.		oP.	Inf.	s. HCl	38
Vit.	Azure B.	B.	Uneven	Fus.	Gelatinous SiO_2 with HCl	39
Vit. py.	W., Y.	W.	Friable	E. fus.	Gelatinous SiO_2 with HCl	40
Vit.	C.	C.	Uneven	E. fus.	Gelatinous SiO_2 with HCl after fusion	41

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Lävenit	$(Mn,Ca,Fe)O.(ZrO,F)$ $Na_2O.2\ SiO_2$	V.	3·51—3·55	6
2	Lazulite	$(Mg,Fe,Ca)\ (Al,OH)_2$ P_2O_8		3—3·12	5—6
3	Leadhillite	$4\ PbSO_4.2\ CO_3.H_2O$	V.	6·3—6·5	2·5
4	Lehrbachite	$PbSe + HgSe$	I.	7·1—7·8	Soft
5	Lepidokrokite	See Göthite.			
6	Lepidolite	$Al_2O_3.3\ SiO_2.(Li,K)_2$ $(F,OH)_2$	V.	2·84—3	2 elastic
7	Lepidomelane	$(K,H)_2O.(Fe,Al)_2O_5.$ $2\ (Fe,Mg)O.3\ SiO_2;$	V.	3	2·5—3 elastic
8	Leucite	$K_2O.Al_2O_3.4\ SiO_2.$	I. & IV.	2·44—2·56	5·5—6
9	Leucophanite	$NaF.CaO.BeO.2\ SiO_2$	IV.h.	2·97	3·5—4
10	Leucopyrites	$FeAs_2$	IV.	6·8—8·71	5—5·5
11	Levyn	$CaO.Al_2O_3.3\ SiO_2.$ $5\ H_2O$	III.rh.h.	2·1—2·2	4
12	Libethenite	$4\ CuO.P_2O_5.H_2O$	IV.	3·6—3·8	4
13	Lièvrite	$(Ca,Fe)O.Fe_2O_3.SiO_2$	IV.	3·9—4·1	5·5—6
14	Lignite	New coal. (Contains larger percentage of H and O			
15	Limestone	$CaCO_3$ in beds			
16	Limonite	$2\ Fe_2O_3.3\ H_2O$	Am.	3·6—4	5—5·5
17	Linarite	$PbSO_4.Cu(OH)_2$	V.	5·3—5·45	2·5—3
18	Linnaeite	$(Co,Ni)_3S_4$	I.	4·8—5·0	5·5
19	Lionite	Impure native Te(q.v.)			
20	Liroconite	$2\ Al_2O_3.2\ As_2O_5.$ $7\ Cu(OH)_2.2\ CuO.$ $20\ H_2O$	V.	2·88—2·98	2—2·5
21	Lithia Mica	See Lepidolite.			
22	Lithomarge	$K_2O.Al_2O_3.2\ SiO_2\ aq$	Am.		1·5—2
23	Liver Ore	See Cinnabar.			
24	Livingstonite	Antimonite (q.v.) with 14% Hg			
25	Lodestone	See Magnetite.			
26	Löllingite	Fe_2As_3	IV.	6·2—7·45	5—5·5
27	Loranskite	See Euxenite.		4·6	5
28	Lovenite	$(Zr,Ca,Na_2)O.SiO_2$	V.		
29	Löweite	$2\ MgSO_4.2\ Na_2SO_4.$ $5\ H_2O$	II.	2·37	2·5—3
30	Ludlamite	$Fe_3(PO_4)_2\ aq$	V.		
31	Ludwigite	$3\ MgO.B_2O_3 + Fe_3O_4$	IV.	3·9—4·1	5
32	Lydian Stone	Jasper (q.v.). [Velvet-black variety. Used for			
33	Magnesia Mica	See Biotite.			
34	Magnesite	$MgCO_3$	III.rh.	3	3·5—4·1
35	Magnetic Iron Ore	See Magnetite.			
36	Magnetic Pyrites	See Pyrrhotine.			
37	Magnetite	$FeO.Fe_2O_3$ or Fe_3O_4	I.	4·9—5·2	5·5—6·5
38	Magnolite	Hg_2TeO_4	V.		5·5
39	Malachite, Blue	See Azurite			
40	—; Green or true	$CuCO_3.Cu(OH)_2$	V.	3·7—4	3·5—4
41	Malacolite	White Augite (q.v.).			

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit.	C., Y., R.Br., Bl.Br.	Br.Y.	$\infty P \bar{\infty}$	E. fus.	Decomp. hot H_2SO_4	1
Vit.	B.		Uneven	Inf.	s. HCl after heating	2
Greasy ad.	Y.W., Gr., Br.		oP.	Fus.	s. HNO_3 with sepn. of $PbSO_4$	3
Met.	Gr., Gr.Bl.	G.	$\infty O \infty$	Sublimes		4
						5
Py.	P.	P.	oP.	2—2·5	Decomp. HCl after fusion	6
Py.	Bl.	Gr.	oP.	4	Decomp. HCl with formn of SiO_2	7
Vit.	W., Gr., tl.ôp.	W.C.	Brittle	Inf.	s. HCl	8
Vit. greasy	G., G.Y., C., W.	Y.W.	oP.	Fus.	s. HF	9
Met.	Silver W.	Gr.Bl.	Brittle	As_2O_3 fumes		10
	C.		Flat	3	Gelatinous SiO_2 with HCl	11
Greasy	Olive G.	G.	Uneven	2	s. HNO_3	12
Vit. greasy	Bl., Br.Bl., G.Bl.	Bl.	Conch., uneven	2·5	Gelatinous SiO_2 with HCl	13
than anthracite.)						14
						15
Sub.met., sy	Br., Y.	Y.Br.	Earthy	Inf.	s. HCl	16
Ad.	Azure B.	Pale B.	$\infty P \bar{\infty}$, oP	Fus.	s. HNO_3 with sepn. of $PbSO_4$	17
Met.	Steel Gr.— R.	Bl.Gr	Brittle	Fus.	s. HNO_3	18
						19
Vit fatty	B., G.	G., B.	Uneven	Fus.	s. HNO_3 and NH_4OH	20
						21
Greasy	W., Y., R.	Shining		Inf.	Ins.	22
						23
		R.				24
						25
Met.	W., Gr.	Bl.	oP	D. fus.	s. HNO_3 with sepn. of As_2O_3	26
						27
	Br., Y.	Y.Br.				28
Vit.	W., Y., R.	W.		Fus.	s. H_2O	29
	G.					30
	Bl.G., Bl.	?		6	E.s. HCl	31
rying purity	of gold alloys.					32
						33
Vit., dull, sy	W., Gr.W., Y., Br.	W.	Even	Inf.	s. hot HCl	34
						35
						36
Met. or sub-met.	Iron Bl. op.	Bl.	Sub. conch.	6	s. HCl	37
y.	W.	W.				38
						39
it. sy.	Bright G. W., Gr.	Pale G.		Fus.	s. HCl, HNO_3	40
						41

	Name.	Composition.	Cryst. System.	Specific Gravity.	
1	Malacon	Partially decomposed Zirkon contg. Ce, Y, Th, Fe, Ca, Mg, 3–9% H_2O	II.	$3 \cdot 9 - 4 \cdot 1$	6
2	Mallardite	$MnSO_4.7\ H_2O$	V.		$3 \cdot 5$
3	Manganblende	See Alabandin.			
4	Manganepidote	$H_2O.4\ CaO.\ 3\ (Al,Mn)_2O_3.6\ SiO_2$	V.	$3 \cdot 4$	$6 \cdot 5$
5	Manganese Spar	See Rhodonite.			
6	Manganite	$Mn_2O_3.H_2O$	IV.	$4 \cdot 2 - 4 \cdot 4$	4
7	Manganosite	MnO	I.	$5 \cdot 18$	$5 - 6$
8	Manganostilbite	MnS with As_2S_3 and Sb_2S_3			
9	Manganotantalite	$MnO.Ta_2O_5$, with Sn & W	IV.	$7 - 8$	$6 - 6 \cdot 5$
10	Marble	$CaCO_3$			
11	Marcasite	FeS_2	IV.	$4 \cdot 6 - 4 \cdot 85$	$6 - 6 \cdot 5$
12	Margarite	$CaO.2\ Al_2O_3.2\ SiO_2.\ H_2O$	IV.	$2 \cdot 99$	$3 \cdot 5 - 4 \cdot 5$
13	Marialite	$2\ NaCl,\ 3\ Na_2O.\ 3\ Al_2O_3.18\ SiO_2$	II.pyr.h.	$2 \cdot 57$	$5 \cdot 5 - 6$
14	Martite	See Hematite. (Octahedral.)			
15	Mascagnine	$(NH_4)_2SO_4$	IV.	$1 \cdot 7 - 1 \cdot 8$	$2 - 2 \cdot 5$
16	Masonite	See Chloritoid.			
17	Matlockite	$PbO.PbCl_2$	IV.	$7 \cdot 2$	$2 \cdot 5 - 3$
18	Maxite	See Leadhillite.			
19	Meerschaum	See Sepiolite.			
20	Mejonite	$4\ CaO.3\ Al_2O_3.6\ SiO_2$	II.pyr.h.	$2 \cdot 7 - 2 \cdot 8$	$5 \cdot 5 - 6$
21	Melaconite	CuO	Am.	$6 \cdot 25$	3
22	Melanite	See Garnet, Iron-lime.			
23	Melanocerite	Ce and Y fluosilicate with C, B, Ta, &c.	III.rh.	$4 \cdot 15$	$5 \cdot 5 - 6$
24	Melanochroite	$PbCrO_4$, impure	?	$5 \cdot 75$	
25	Melanosiderite	$Fe_2O_3.xH_2O$, $7 \cdot 42\%\ SiO_2$	Am.		
26	Melanterite	See Copperas.			
27	Meliphanite	$2\ (Mg,Fe)O.SiO_2$ contg. Be	IV.	$3 \cdot 018$	$6 - 7$
28	Melinophane	See Meliphanite.			
29	Melilite	$6\ (Ca,Mg,Na_2)O.\ (Al,Fe)_2O_3.5\ SiO_2$	II.	$2 \cdot 9 - 3 \cdot 1$	$5 - 5 \cdot 5$
30	Melonite	$NiTe$	III.		$5 - 5 \cdot 5$
31	Menaccanite	See Ilmenite.			
32	Mendipite	$2\ PbO.PbCl_2$	IV.	$7 - 7 \cdot 1$	$2 \cdot 5 - 3$
33	Mendozite	See Alum, Soda.			
34	Meneghinite	$4\ PbS.Sb_2S_3$	IV.	$6 \cdot 3$	3
35	Menilite	Opal (reniform)	Am.		
36	Mercury	Hg	I. ($-40°C.$)	$13 \cdot 56$	

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
	B.W., Br., Bl.			Inf.		1
Vit.	W., P., Y.	W.		Fus.	s. H_2O	2
						3
Vit.	Dark R.	R.	oP.	E. fus.	Gel. SiO_3 with HCl after heating to redness.	4
						5
Sub-met.	Bl.Gr.op.	R.Br.—Bl.	Uneven	Loses H_2O	s. HCl	6
Vit.	Emerald G.—Br.	G.		Inf.		7
						8
Sub-met.	Br.Bl.	Br.R.	Brittle	Inf.		9
	W., P., or streaked					10
Met.	Whitish Y.	Br.Bl.	Brittle	Fus.	s. HNO_3 with sepn. of S	11
Py. vit.	W., P.W., Y., Gr.	W., P.W.	Mica-like	D. fus.	Ins.	12
Vit.	G.W., Gr.		$\infty P \infty$	3	Ins.	13
						14
Vit.	Y.Gr., tl.—op.	C.	oP.	E.fus. volatilises	E.s. H_2O	15
						16
Ad.	G.Y.	W.G.	Conch., uneven	E. fus.	s. HNO_3	17
						18
						19
Vit.	C., W., Gr.		$\infty P \infty$	3	Decomp. HCl	20
Dull	Bl.	Bl.	Earthy	Inf.	s. ac.	21
Dull or vit.	Bl.					22
Greasy vit.	Br.Bl.	Br.	Conch.	Inf.	s. hot HCl with sepn. of SiO_3	23
	Dark R.	Brick R.				24
Vit.	Br.R.	Br.	Conch.	Fus.	Gelatinous SiO_3 with HCl	25
						26
Vit.	Y.	Y.		Inf.	Decomp. HCl	27
						28
Vit. wax.	C., W., Y., Br.	W.	oP.	Fus.	Gelatinous SiO_4 with HCl	29
Met.	R.W.	P.W.				30
						31
Py.	W., Y., R.op.	W.	$\infty P.$	E. fus.	E.s. HNO_3	32
						33
Met.	W.Gr.	Gr.		E. fus.	s. HNO_3 with sepn. of S and Sb_2O_3	34
	Br.op.					35
Met. splendent	W.op		Liquid	Volatilises	s. HNO_3	36

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Mercury Sulphide	See Cinnabar.			
2	Meroxene	$(K,H)_2O.(Fe,Al)_2O_3.$ $2 (Fe,Mg)O.3 SiO_2$	V.	$2\cdot8—3\cdot2$	2
3	Mesitine Spar	$(Mg,Fe)CO_3$	III.rh.h.	$3\cdot3—3\cdot4$	$3\cdot5—4$
4	Mesolite	$Na_2O.Al_2O_3.3 SiO_2.$ $2 H_2O$ $Ca(OH)_2.Al_2O_3.3 SiO_2.$ $2 H_2O$	V.	$2\cdot2—2\cdot4$	5
5	Mesotype	See Natrolite.			
6	Metacinnabarite	HgS	I.tetr.h.	$7\cdot7—7\cdot8$	3
7	Miargyrite	$Ag_2S.Sb_2S_3$	V.	$5\cdot2—5\cdot4$	$2—2\cdot5$
8	Mica	(See Muscovite, Biotite, Lepidolite, Phlogopite, &c.)			
9	Microcline	$K_2O.Al_2O_3.6 SiO_2$	VI.	$2\cdot5—2\cdot6$	6
10	Microlite	$2 [Ca,Mn,Fe,Mg]O.$ $[Ta,Nb]_2O_5$	I.	$5\cdot5—5\cdot6$	$5—6$
11	Miemite	$CaCO_3.MgCO_3$	IV.	$2\cdot7—2\cdot95$	$3\cdot5—4$
12	Millerite	NiS	III.rh.	$4\cdot6—5\cdot6$	$3—3\cdot5$
13	Mimetisite	See Mimetite.			
14	Mimetite	$3 [3 PbO.As_2O_5]. PbCl_2$	III.	$7—7\cdot25$	$3\cdot5$
15	Mineral Coal	See Coal—Mineral.			
16	— Oil	C_nH_{2n+2} series		<1	
17	— Pitch	See Asphaltum.			
18	Minium	Pb_3O_4	Am	$4\cdot6$	$2—2\cdot5$
19	Mirabilite	$Na_2SO_4.H_2O$	V.	$1\cdot4—1\cdot5$	$1\cdot5—2$
20	Mispickel	$FeAsS$ or $FeAs_2.FeS_2$	IV.	$5\cdot7—6\cdot3$	$5\cdot5—6$
21	Mixite	$Cu_3O.As_2O_5.x H_2O$ with 13% Bi_2O_3	IV.pris.		
22	Mocha Stone	Chalcedony with dendrites of Fe_2O_3 or ferruginous			
23	Molybdate, Lead	See Wulfenite.			
24	Molybdenite	MoS_2	III.	$4\cdot45—4\cdot8$	$1—1\cdot5$
25	Molybdic Ochre	MoO_3	IV.	$4\cdot5$	$1—2$
26	Molybdite	See Molybdic Ochre.			
27	Monazite	$[Ce,La,Di] PO_4$ contg. Th	V.	$4\cdot9—5\cdot25$	$5—5\cdot5$
28	Montmorillonite	$Al_2O_3.SiO_2$ aq			Soft
29	Monticellite	$2 [Ca,Mg]O.SiO_2$	IV.	$3\cdot3—3\cdot6$	$6—7$
30	Moonstone	Opalescent or pearly variety of Adularia.			
31	Morenosite	$NiSO_4.7 H_2O$			$4—4\cdot5$
32	Mosandrite	$3 [CaO.(SiO_2, TiO_2)]$ $(Ce,La,Di)_4O_3.$ $(SiO_2,TiO_2)_2]$	V.	$2\cdot9—3\cdot03$	4
33	Moss Agate	See Mocha Stone.			
34	Mountain Cork	Asbestus (q.v.). (Has elasticity of cork.)			

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
						1
Py.	Y., G., Bl.		oP.	4	Decomp. H_2SO_4	2
Vit.	Y., Br.			Inf.	s. hot HCl	3
Vit.	C., W., Gr., Y.		∞P	2	Gelatinous SiO_2 with HCl	4
						5
	Gr.Bl.	Bl.	Conch., uneven	Sublimes	s. HNO_3+ HCl	6
Met. ad.	Iron Bl.	Dark cherry R.	Conch., uneven	E. fus.	s. HNO_3 with sepn. of S and Sb_2O_3	7
Muscovite is common Mica.						8
Vit. py.	C., W., Y., P., G.		oP, ∞P∞	5	Ins.	9
Greasy vit.	Y., R., Br.		Conch., uneven		Decom. H_2SO_4 with sepn. of white powder	10
Vit. py.	Y.Br.	Y.Br.	Fibrous	Inf.	s. hot HCl	11
Met.	Brass Y.—bronze Y.	Bright	Brittle	E. fus.	s. HNO_3	12
						13
Res.	Pale Y., Br. or W.	W.	Conch.	As_2O_3, and $PbCl_2$ volatilise E. fus.	s. HNO_3 and KOH	14
						15
	C. or pale Y.			Burn		16
						17
Dull	R., Y.	Or.	Even, conch, or earthy	1	Decomp. HCl with sepn. of $PbCl_2$	18
Vit.	C.		∞P∞	E. fus.	s. H_2O	19
Met. shining	Silver W.—steel Gr.	Dark Gr.Bl.	Brittle	E. fus.	s. HNO_3 with sepn. of S and As_2O_3	20
	Emerald—B.G					21
chlorite.						22
						23
Met.	W., Gr.	Gr.G. shining	oP.	Inf.	s. HNO_3 with sepn. of H_2MoO_4 aq	24
Sy.	W.Y.	Y.	oP.	E. fus.	E.s. HCl	25
						26
Greasy	Br., R., Y.	?	oP.	D. fus.	s. HCl, gives white ppt.	27
	Rose R.-W.or B.		Earthy			28
Vit.	Bottle G.			Inf.	Gelatinous SiO_2 with HCl	29
						30
	Apple G.	Pale G.				31
Greasy, vit.	R.Br., G., Y.Br.	Y.	∞P∞	Fus.	s. HCl with sepn. of SiO_2	32
						33
	W. or Gr.W.					34

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Mountain Leather	Asbestus (q.v.). (Thin tough sheets, somewhat like			
2	— Tallow	See Hatchettine.			
3	Müller's glass	See Hyalite.			
4	Mundic	Iron-pyrites (q.v.). Miners' name for pyrites.			
5	Muriacite	See Anhydrite.			
6	Muscovite	$2 H_2O.K_2O.3 Al_2O_3.$ $6 SiO_2$	V.	2·7—3·1	2—2·5
7	Muscovy glass	See Muscovite.			
8	Nadorite	PbO.SbOCl	IV.	7—7·1	3
9	Nagyagite	10 PbS.Sb$_2$S$_3$.2 AuTe$_2$ or 2 AuS	IV.	7·085	1—1·5
10	Nakrite	$Al_2O_3.2 SiO_2.H_2O$	V. crystalline	2·63	1
11	Naphtha	Oil of $C_nH_{2n}+_2$ series		<1	
12	Natrocalcite	See Gaylussite.			
13	Natrolite	$Na_2O.Al_2O_3.3 SiO_2.$ $2 H_2O$	IV.	2·24—2·25	5—5·5
14	Natron	$Na_2CO_3.10 H_2O$	V.	1·42	1—1·5
15	Naumannite	$(Ag_2,Pb)Se$	I.	8	2—2·5
16	Needle Ore	See Aikenite.			
17	Nemalite	Brucite (q.v.).			
18	Neocianite	$CuO.SiO_2$	V.		
19	Neolite	$(Mg,Fe)O.Al_2O_3.$ $x SiO_2.n.H_2O$	Crystalline	2·8	1
20	Neotype	See Alstonite.	III.	2·82	
21	Nepheline	$3 (Na_2,K_2)O.4 Al_2O_3.$ $9 SiO_2$	III.	2·55—2·62	5·5—6
22	Nephrite	See Jade.			
23	Niccolite	NiAs	III.	7·3—7·6	5—5·5
24	Nickel gymnite	See Genthite.			
25	— pyrites	See Millerite.			
26	— stibine	See Ullmannite.			
27	— vitriol	See Morenosite.			
28	Niobite	$(Fe,Mn)O.(Nb,Ta)_2O_5$	IV.	5·4—6·5	5—6
29	Nitrate, Calcium	$Ca(NO_3)_2$	IV.?		
30	— Potassium	KNO_3	IV.	1·97	2
31	— Sodium	$NaNO_3$ (deliquescent)	III.rh.	2·09—2·29	1·5—2
32	Nitratine	See Nitrate, Sodium.			
33	Nitre	See Nitrate, Potassium.			
34	Nitrobarite	$Ba(NO_3)_2$			1·5—2·5
35	Nitrocalcite	See Nitrate, Calcium.			
36	Nitromagnesite	$Mg(NO_3)_2$	Am.	2·3—2·7	1—2
37	Nosean	$2 Na_2O.Al_2O_3.3 SiO_2$ $+ Na_2SO_4$	I.	2·25—2·6	5·5—6
38	Nouméite	See Garnierite.			
39	Ochre, Brown	See Limonite.			
40	— Red	See Hematite, Red.			
41	— Yellow	See Limonite.			
42	Octahedrite	See Anatase.			
43	Odontolite	See Bone Turquois.			
44	Oerstedtite	Altered Zirkon with H_2O and TiO_2			

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Kid-leather.)						1
						2
						3
						4
						5
Py.	W., Bl., Br., Y., G., Gr.	C.	Flexible, elastic and tough	D. fus.	Decomp. hot H_2SO_4	6
						7
Greasy-ad.	Y., Br.	? .	$\infty P \bar{\infty}$	Fus.	s. HCl	8
Met.	Bl.Gr.	Bl.Gr.	$\infty P \infty$	E. fus.	s. HNO_3 with sepn. of Au	9
Py.	W.Gr.		oP.	Inf.	Decomp. HCl	10
						11
						12
Vit.	W., Y., Gr.R.		Brittle	E. fus.	Decomp. HCl	13
Vit. or earthy	W., Y., Gr.	C.		E. fus.	s. H_2O	14
Met.	Iron Bl.	Gr.Bl.		E. fus.	s. HNO_3	15
						16
			Fibrous			17
Dull	Bright B.	Pale B.				18
Vit.	W., Gr., P., Y	Shining	Flaky, fibrous, earthy			19
						20
Vit.— greasy	W., Gr., Y., G., B.R.		Sub-conch.	Fus.	Gel. SiO_2 with ac.	21
						22
Met.	Pale copper R	Pale Br.Bl.	Brittle	Fus.	s. $HNO_3 + HCl$	23
						24
						25
						26
						27
Sub-met.ad.	Iron Bl., Br.Bl.	Bl.Br., R.	Brittle	Inf.	Ins.	28
						29
Vit.	C., W.	C.	Conch.	E. fus.	s. H_2O	30
Vit.	W., Gr., Br.	C.	Conch.	E. fus.	s. H_2O	31
						32
						33
	W., C., Y.	C.			s. H_2O	34
						35
Deliquescent	W.	W.	Earthy	E. fus.	s. H_2O	36
Vit.	Gr., W., G., B., Bl.	W.	∞O	Fus.	Gelatinous SiO_2 with HCl	37
						38
						39
						40
						41
						42
						43
Ad.	R.Br.			Inf.		44

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Oligoclase	Ab_6An_1—Ab_2An_1.* Mostly Ab_2An_1	VI.	2·58—2·7	6
2	Olivenite	$4 CuO.As_2O_4$	IV.	4·13—4·38	3
3	Olivine	See Chrysolite.			
4	Onofrite	$Hg(S,Se)$	Am.	7·62	
5	Onyx	Chalcedony (q.v.). [Flat-banded variety.]			
6	Oölite	Compact $CaCO_3$. (Round concretionary grains, size			
7	Opal	SiO_2 compact, reniform or stalactitic	Am.	2·21	5·5—6·5
8	Opal Jasper	SiO_2. (Resembles jasper but is not so hard.)			
9	Ophiolite	Serpentine with limestone			
10	Orangite	$ThSiO_4$ with CaO. $(Fe,Mn)_2O_3, UO_3$	Am.	1·9—2·3	5·5—6·5
11	Orpiment	As_2S_3	IV.	3·4—3·5	1·5—2
12	Orthite	$(Al,Ce,Fe)_3 (AlOH)$ $Ca_2Si_3O_{12}$	V.	3—4	5·5—6
13	Orthoclase	$K_2O.Al_2O_3.6 SiO_2$	V.	2·39—2·62	6
14	Osteolite	Impure Apatite (q.v.)			
15	Ostranite	See Zirkon.			
16	Ouvarovite	See Garnet, Lime-Chrome.			
17	Ozokerite	As for Hatchettine	Am	$1\frac{1}{2}$—2	0·5—1
18	Pachnolite	$NaF.CaF_2.AlF_3.H_2O$	V.	2·15—2·3	2·5—3
19	Pagodite	See Pinite.			
20	Palladium	$Pd(Pt, Ir)$	I.	11·3—12·2	4·5—5
21	Pandermite	$3 CaO.4 BO_3.6 H_2O$	Am	2·26—2·48	3
22	Paragonite	Like Muscovite (q.v.)	Am.	2·75—2·9	
23	Paranthine	See Scapolite.			
24	Pargasite	A pyroxene		3·11	
25	Parisite	$(CeF)(CaF_2)CeCO_3,$ with La and Di	III.	4·35	4—5
26	Pattersonite	See Thuringite.			
27	Pearl Sinter	SiO_2			
28	—Spar	Dolomite	III.rh.		
29	Pectolite	$4 CaO.Na_2O.H_2O.$ $6 SiO_2$	V.	2·86—2·88	5
30	Peganite	See Variscite.			
31	Pegmatolite	Orthoclase (q.v.)			
32	Pelagite	$xMnO_2.yFe_2O_3.zH_2O$	Am.		
33	Pencil-stone	See Pyrophyllite.			
34	Pennine	$4 H_2O.(Al,Fe)_2O_3.5$ $(Mg,Fe)O.3 SiO_2$	III.rh.	2·6—2·75	2—2·5
35	Penninite	See Pennine.			
36	Periclase	MgO	I.	3·674	6
37	Pericline	See Albite.			
38	Peridot	See Chrysolite.			
39	Peristerite	Albite with disseminated grains of quartz.			
40	Perowskite	$CaO.TiO_2$	I.	3·95—4·0	5·5—6
41	Petalite	$Al_2O_3.Li_2O.8 SiO_2$	V.	2·4—2·5	6—6·5

*Ab = Albite , An = Anorthite.

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Res.vit.py.	Gr., G., Y., W	C.	Conch., uneven	Fus.	Ins. ac.	1
Vit. ad.	Olive G.—wood Br.	Olive G.—Br.	Brittle	E. fus.	s. HNO₃	2
						3
Met.	Bl.Gr.	Bl.Gr.	Massive			4
						5
of fish spawn n.)						6
Sub-vit.	Opalescent	C.	Conch.	Inf.	Ins.	7
Res.						8
	G. clouded, marble					9
Greasy	R.Y.		Conch., uneven	Inf.	s. HF and hot KOH	10
Py. res. dull	Fine Y	Y	Sectile, flexible	As₂O₃ volat.		11
Vit. py.	Gr., Br., Bl.	G.Gr.,Br	Conch.	Fus.	Sometimes ins. in acids.	12
Vit. py.	W., R.W., P. C., Y., G.	Gr.W.	Conch., splintery	5	Decomp. HF	13
	W. earthy					14
						15
						16
Wax.	Dark Y. or Br	W.		130-140° F		17
Vit.	C.,W.,Y.,	C.	Uneven	E. fus.		18
						19
Met.	Steel Gr.—silver W.	Gr.W. shining	Malleable	Inf. alone	s. HNO₃	20
Dull	W.Gr.	W.				21
Py.	W., G., Y.		Sectile	Inf.		22
						23
Bright vit.						24
Sy., py.	Y.Br.	Y.W.	oP.	Inf.	D.s. HCl	25
						26
Py.						27
Py.	(Crystals have	curved	faces.)			28
Vit. py	W.Gr.		∞P ∞̄, oP	2	s. HCl with sepn. of flocculent SiO₂	29
						30
						31
Dull	Br.Bl.	Br.	Concretion'y	Inf.	s. HCl	32
						33
Py.	G., Y.—W., R.—V.		Flexible	D. fus.	Decomp. H₂SO₄	34
						35
Vit.	Dark G. W. semi-op.	G.W.	∞O ∞	Inf.	D.s. HCl	36
						37
						38
						39
Ad.	Y., Br., Bl.	W., Gr.	∞O ∞	Inf.	Decomp. hot H₂SO₄	40
Vit. py.	C., W., Gr., ,P., G.W.	W.		D. fus.	Decomp. HF	41

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Petrified Wood	SiO_2	(Silica re	places the	original
2	Petroleum	Mainly $C_nH_{3n}+_3$series	Liq.	·60—·85	—
3	Petzite	$(Ag, Au)_2Te$	I.	8·7—9·4	2·5—3
4	Phacolite	See Chabazite.			
5	Pharmacolite	$2\ CaO.As_2O_5.5\ H_2O$	V.	2·6—2·7	2—2·5
6	Pharmacosiderite	$3\ As_2O_3.Fe_2O_3.3\ FeOH$ $.12\ H_2O$	I.	3	2·5
7	Phenacite	$BeSiO_4$	III.rh.	3	7·5—8
8	Phengite	Muscovite (q.v.). (Co	ntains mor	e silica.)	
9	Philippite	$CuSO_4.FeSO_4.x\ H_2O$			
10	Phillipsite	$(Ca,Na_2,K_2)O.Al_2O_3.$ $6\ SiO_2+6\ H_2O$ $(Ca,Na_2,K_2)O.2\ Al_2O_3.$ $4\ SiO_2+6\ H_2O$	V.	2·2—2·4	4—4·5
11	Phlogopite	$3\ (K_2,H_2)O.6(Mg,Fe)$ $O.(Al_2,Fe_2)O_3.6SiO_2$	V.	2·8—3·2	2—3
12	Phœnicochroite	$PbCrO_4$	II.	5·75	
13	Phosgenite	See Horn Lead.			
14	Phosphate, Aluminium	See Wavellite.			
15	—Ammonium	See Struvite.			
16	—Calcium	See Apatite.			
17	—Cerium	See Monazite.			
18	—Copper	See Pseudomalachite	and Libeth	enite.	
19	—Iron	See Vivianite.			
20	—Lead	See Pyromorphite.			
21	—Manganese	See Triphylite.			
22	—Uranium	See Torbernite.			
23	—Yttrium	See Monazite.			
24	Phosphocalcite	See Pseudomalachite			
25	Phosphocerite	See Rhabdophane.			
26	Phosphochalcite	See Pseudomalachite.			4·5—5
27	Phosphorite	See Apatite.			
28	Phosphuranylite	$(U,Pb)O.P_2O_5.$ aq	Am		
29	Phyllite	See Chloritoid			
30	Physalite	$Al_2O_3.SiO_2$	IV.	3·4—3·65	8
31	Pickeringite	See Alum-Magnesia.			
32	Picotite	$MgO.Al_2O_3$ with Fe and 7% CrO_3	I.	4·08	8
33	Picromerite	$(K_2,Mg)SO_4.$ aq	IV.		2—2·5
34	Piedmontite	$H_2O.4\ CaO.$ $3(Al,Mn)_2O_3.6\ SiO_2$	V.	3·4	6·5
35	Pimelite	Meerschaum contg. Ni	Am	2·2—2·8	2·5
36	Pinite	$2\ Al_2O_3.K_2O.3\ H_2O.$ $5\ SiO_2$	Am.	2·6—2·7	2·5—3·5
37	Pisolite	$CaCO_3$. (Compact, ro	und, concre	tionary gra	ins, the
38	Pistacite	Epidote (q.v.)			
39	Pitchblende	$UO.U_2O_3$	I.	6·4—9·7	5·5
40	Pitticite	See Scorodite.			
41	Plagioclase	General Name for tric	linic felspa	rs. See Al	bite,

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
structure.)						
	C.			Burns		1
Met.	Gr., Gr.Bl.	Shining	Conch.	E. fus.	s. HNO₃	2
	C. lenticular crystals					3
						4
Vit.—py.	C.W.		∞P∞	E. fus.	s. HNO₃	5
Ad.	Dark G., Br., R.	G.Br.				6
Vit.	C., Y., W., Gr.		Conch.	Inf.	Ins.	7
						8
	Azure B.					9
Vit.	C., Gr., W., Y., P.		∞P∞, oP	Fus.	s. HCl with sepn. of gelatinous SiO₂	10
Py.	C., Y., R. Br., G., Bl.		oP	4	Decomp. H₂SO₄	11
	Dark R.	Brick R.				12
						13
						14
						15
						16
						17
						18
						19
						20
						21
						22
						23
						24
						25
	Emerald or Bl.G.					26
						27
Dull	Lemon Y.	Y.	Brittle			28
						29
Vit.	Nearly op. Y.W.	Y.W.	Conch.	Intumesces	Ins.	30
						31
Vit.	Bl.	Bl.	Conch.	Inf.	Ins.	32
Earthy	W.	W.	Earthy	Fus.	s. H₂O	33
Vit.	R.Br., Bl.R., R.	R.	oP	E. fus.	Gel. SiO₂ after heating to redness and adding HCl	34
Greasy	G.		Conch.	6		35
Wax.	Gr.G., Br.R.		Brittle	Inf.		36
size of a sm	all pea.)					37
	G.					38
Sub-met., greasy, pitch-like, dull	Gr., Br., velvet Bl.	Bl.Gr. or G.		Inf.	s. HNO₃	39
						40
Oligoclase,	Andesine, Lab	radorite,	etc.			41

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Plagionite	5 PbS.4 Sb₂S₃	V.	5·4	2·5
2	Plasma	SiO_2 (chalcedony).			
3	Plaster of Paris	Dehydrated Gypsum.			
4	Platiniridium	Pt + Ir(Rh,Pd,Cu)	I.	22—23	6—7
5	Platinum	Pt(Ir,Rh,Pd,Os,Cu)	I.	17—18	4—4·5
6	Pleonast	$(Mg,Fe)O.(Al;Fe)_2O_3$	I.	3·6—3·7	8
7	Plessite	See Gersdorffite.			
8	Plumbago	See Graphite.			
9	Plumbogummite	$PbO.Al_2O_3.$ aq	Globular	6·3—6·4	4—4·5
10	Polianite	MnO₂. (See Pyrolusite.)			
11	Pollucite (Pollux)	$H_2O.Al_2O_3.Cs_2O.5 SiO_2$	I.	2·868	6—7
12	Polyargyrite	12 Ag₂S.Sb₂S₃		6·2—6·5	2—2·5
13	Polybasite	9 (Ag,Cu)₂S.(Sb,As)₂S₃	IV.	6·2—6·3	2—2·5
14	Polydymite	(Ni,Co)₄S₅	I.	4·8	4·5
15	Polyhalite	2 CaO.MgO.K₂O. 4 SO₃.2 H₂O	V.	2·72—2·77	3—3·5
16	Polycrase	Similar to Euxenite (q.v.)	IV.	4·7—5·1	5—6
17	Polymignite	4(Ca,Ce,Fe)O.(Ti,Zr)O₂ CaO.Nb₂O₅	IV.	4·77—4·85	6—6·5
18	Porcelain Jasper	A baked clay.			
19	Porpezite	Au with 7—11% Pd	I.	11—15	
20	Potash Mica	See Muscovite.			
21	Potstone	2 (CaO.SiO₂)+Al₂O₃. SiO₂+H₂O			
22	Prase	SiO_2 (quartz)	III.rh.	2·5—2·8	7
23	Praseolite	Decomposed Cordierite	IV.	2·75	3—4
24	Prehnite	$H_2O.2 CaO.Al_2O_3.$ 3 SiO₂	IV.	2·8—2·95	6·5—7
25	Priceite	3 CaO.4 BO₃.6 H₂O	Am.	2·262	
26	Prochlorite	Similar to Pennine and chlorite	III.	2·75—3	2—2·5
27	Proidonite	SiF₄			
28	Prosopite	Ca(F,OH)₂.Al₂(F,OH)₆	V.	2·8—2·9	4—5
29	Proustite	3 Ag₂S.+As₂S₃	III.rh. h.	5·4—5·6	2—2·5
30	Pseudobrookite	2 Fe₂O₃.3 TiO₂	IV.	4·9—5·0	6
31	Pseudomalachite	Cu₃(PO₄)₂ aq.	V.	4—4·4	4·5—5
32	Psilomelane	$MnO_2+(Mn,Ba,K_2)O.$ + xH₂O	Am.	3·7—4·7	5—6
33	Pucherite	Bi₂O₃.V₂O₅	IV.	6·25	6
34	Purple Copper	See Bornite.			
35	Pyrargyrite	3 Ag₂S.Sb₂S₃	III.rh.	5·7—5·9	2—2·5
36	Pyreneite	See Garnet, Iron-lime.		3·64—4	
37	Pyrites, Arsenical	See Mispickel.			
38	— Auriferous	Iron pyrites contg. Au			

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Met.	Gr.	Gr.		E. fus.	s. HCl with sepn. of $PbCl_2$	1
	Tl.G. sprinkled with W. & Y. dots.					2
						3
Met.	W., Gr.	Gr. shining	Hackly	Inf.	s. HNO_3+HCl	4
Met.	Gr.	Gr.	Hackly	Inf.	s. HNO_3+HCl	5
Vit.	Gr., Bl.	Dark Gr.	Conch.	Inf.	Ins.	6
						7
						8
Like gum-arabic	Y.Br., R.Br.	Light R.	Earthy	Inf.		9
						10
Vit.	W.		Conch.	D fus.	Decomp. HCl	11
Met.	Gr.Bl.	Gr.Bl.	Brittle	E. fus.	Decom. HNO_3	12
Met.	Gr.Bl.	Bl.	Uneven	E. fus.	Decom. HNO_3	13
Brilliant met.	Gr.	Bl.Gr.	$\infty O \infty$	E. fus.	s. HNO_3	14
Almost greasy	C., W., R.		Fibrous	3	s. H_2O	15
Met.	Bl.	Gr.Br.	Conch.	Inf.	s. H_2SO_4	16
Nearly met.	Bl.	Bl.Br.	Conch.	Inf.	Decom. H_2SO_4	17
	Gr.—R.		As for flint	Somewhat fus.		18
Met.	Y.W.	Shining	V.malleable	Fus.	s. Aqua-regia	19
						20
	Gr.G., Gr. G., or Br.Bl.		Can be turned on a lathe.			21
Vit.	Leek G.			Inf.		22
Greasy	G.			Fus.		23
Vit.	G.		oP.	2	Gelatinous SiO_2 with HCl	24
Dull	W. chalky	W.	Chalky	Fus.	s. hot H_2O	25
Py.	G.—Bl.G.	G.	*Not* elastic	D. fus.	Decom. H_2SO_4	26
						27
Vit.	W., Gr., C.		Conch.			28
Splendent	Light cochineal R.	Cochineal R.	Conch.	E. fus.	s. HNO_3 with sepn. of S and As_2O_3	29
Vit.	R.Br., Bl.	Br.	$\infty P \bar{\infty}$	Inf.	s. H_2SO_4	30
Greasy	Emerald or Bl.G.	G.	Uneven, brittle	E. fus.	s. HNO_3	31
Dull	Bl.Gr.	Br.Bl. shining	Even, conch.	Inf.	s. HCl	32
Vit. ad.	R., Br.		oP	E. fus.	s. HCl	33
						34
Met. ad. splendent	Bl.—dark cochineal R.	Cochineal R.	R.	1.	s. HNO_3 with sepn. of S and Sb_2O_3	35
						36
	Bl.					37
						38

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Pyrites, Capillary	See Millerite.			
2	— Cobalt	See Smaltine.			
3	— Coxcomb	See Marcasite.			
4	— Copper	$CuFeS_2$	II.	4·15—4·3	3·5—4
5	— Iron	FeS_2	I.	4·8—5·1	6—6·5
6	— Magnetic	See Pyrrhotine.			
7	— Radiated	See Marcasite.			
8	— White Iron	See Marcasite.			
9	Pyrochlore	$(Ca,Fe,Ce)O.$ $(Nb,Ti,Th)O_2.+H_2O$	I.	4·2—4·5	5—5·5
10	Pyrochroite	$Mn(OH)_2.$	Am.		
11	Pyrolusite	$MnO_2.$	H.m.	4·8—5	2—2·5
12	Pyromorphite	$3 (3 PbO.P_2O_5)+$ $PbCl_2$	III.	6·5—7·1	3·5—4
13	Pyrope	See Garnet, Magnesia-Alumina.			
14	Pyrophyllite	$Al_2O_3.H_2O.4 SiO_2$	IV.	2·75—2·92	1—2
15	Pyrostilbite	See Kermesite.			
16	Pyrostilpnite	Impure Ag_2S	V.		2—2·5
17	Pyroxene	$CaO.MgO.2 SiO_2$ with $(Mg,Fe)O.(Al,Fe)_2O_3.$ SiO_2	(See Augite, Wollastonite,		
18	Pyrrhosiderite	See Göthite.			
19	Pyrrhotine	FeS	III.	4·4—4·65	3·5—4·5
20	Quartz	SiO_2	III. trap.	2·5—2·8	7
21	Quicksilver	See Mercury.			
22	Raddle	Red Hematite (q.v.)			
23	Ralstonite	$3 Al(OH,F)_3.$ $(Na_2,Mg)F_2.2 H_2O$	I.	2·56	4·5
24	Ratholite	See Pectolite.			
25	Realgar	As_2S_2	V.	3·4—3·6	1·5—2
26	Red Antimony	See Kermesite.			
27	— Chalk	See Hematite, Red.			
28	— Copper Ore	See Cuprite.			
29	— Hematite	See Hematite, Red.			
30	— Lead	Pb_3O_4	Am.	4·6	
31	— Ochre	See Hematite, Red.			
32	— Silver Ore	See Pyrargyrite.			
33	— Zinc Ore	— Zincite.			
34	Reddle	See Raddle.			
35	Reddingite	$3 (Mn,Fe)O.P_2O_5$ aq	Am.		
36	Redruthite	Cu_2S	IV.	5·5—5·8	2·5—3
37	Reinite	$FeWO_4$	II.pyr.h.	6·64	4
38	Remolinite	See Atacamite.			
39	Rennselaerite	Talc (q.v.).			3—4
40	Retinite	$C_{12}H_{16}O$	Am.	1·05—1·15	1·5—2
41	Retzbanyite	$Pb(Bi,S)$	I.		

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
						1
						2
						3
Met.	Brass Y..	G.Bl. unmet.	Brittle	Fus.	s. HNO₃ with sepn. of S	4
Met.	Brass Y.	G.Bl., Br.Bl.	Conch., uneven, brittle	Fus.		5
						6
						7
						8
Vit. greasy	R.Br., Bl.Br.	Br.	Conch.	D. fus.	Decom. H₂SO₄	9
	W.	W.				10
Met.	Bl.	Bl.	Brittle	Inf.	s. HCl	11
Res.	G., Y., B.	W. or Y.W.	Sub-conch. or uneven, brittle	E. fus.	s. HNO₃	12
						13
Py.	W., Gr.W., G., Bl.		oP	6	Decom. H₂SO₄	14
						15
	Fire R.	R.				16
Spodumene	.)					17.
						18
Met.	R., Br., bronze or copper	Gr.Bl.	Uneven brittle	E. fus.	s. HCl with sepn. of S	19
Vit.	C., Gr.,Y., Br., B., G., P., V.		Conch. splintery	Inf.	D.s. KOH and s. HF	20
						21
Dull			Earthy			22
						23
						24
Res.	R., Orange	R., Orange	Conch.	Burns, giving off As₂O₃ and SO₂	s. HNO₃ with sepn. of S	25
						26
			Compact, fine			27
						28
						29
Dull	Bright R.	R.	Earthy	E. fus.	s. HNO₃	30
			Soft, earthy			31
						32
						33
						34
	Rose P.	P.W.				35
Met.	Blackish-lead Gr.	Lead Gr.–Bl.	Brittle	E. fus.	s. HNO₃ with sepn. of S	36
Vit.	Bl., Br.	Br.		Fus.	Decomp. HCl	37
						38
	W., Y., Bl.					39
Greasy	Y., Br.	W.Y.	Conch.	250° burns		40
Met.	Steel Gr.	Gr.				41

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Rhabdophane	$(Ce,La,Di)_2(PO_4)_3$	I.		
2	Rhodium Gold	$(Rh,Au).Rh=30-45\%$	I.	$15\cdot5-16\cdot8$	
3	Rhodizite	$3\ CaO.4\ B_2O_3.\frac{1}{2}\ CaCl_2$	I.	$2\cdot97-3\cdot5$	7
4	Rhodochrosite	$MnCO_3$	III.rh.	$3\cdot45-3\cdot6$	$3\cdot5-4\cdot5$
5	Rhodonite	$MnO.SiO_2$	VI.	$3\cdot4-3\cdot6$	$5\cdot5-6\cdot5$
6	Rhoetizite	See Kyanite.			
7	Rhomb Spar	Dolomite in rhombs	III.rh.		
8	Richellite	$(Fe,Ca)_4[F_6,(PO_4)_2]$		2	
9	Riebeckite	$Na_2O.Fe_2O_3.4\ SiO_2.$ $4\ FeO.4\ SiO_2$	V.	$3\cdot3-3\cdot4$	?
10	Rinkite	$3NaF.4CaO.6(Si,Ti)O_2.$ Ce_2O_3	V.	$3\cdot46$	5
11	Ripidolite	$4\ H_2O.(Al,Cr)_2O_3.$ $5(Mg,Fe)O.3\ SiO_2$	V.	$2\cdot6-2\cdot75$	$2-2\cdot5$
12	Rivotite	$Cu(CO_3,Sb_2O_4)$			
13	Rock Crystal	See Quartz.			
14	— Meal	$CaCO_3$	Am.	(Deposited from
15	— Milk	Fine quality of Rock Meal.			
16	— Salt	$NaCl$	I.	$2\cdot1-2\cdot2$	$2-2\cdot5$
17	— Tallow	See Hatchettine.			
18	Romeite	$CaO.Sb_2O_5$	II.		
19	Roscoelite	Vanadium-mica			
20	Roselite	$3\ (Ca,Co,Mg)O.As_2O_5.$ $2\ H_2O$	VI.	$3\cdot46$	$3\cdot5$
21	Rosellane (Rosite)	Decomposed Anorthite		$2\cdot72$	
22	Rose Quartz	SiO_2	III. t p.	$2\cdot5-2\cdot8$	7
23	Rothoffite	$6\ (Mn,Ca)O.3\ SiO_2+$ $2\ Fe_2O_3.3\ SiO_2$	I.	$3\cdot6-4$	$6\cdot5-7\cdot5$
24	Röttisite	$2\ NiO.3\ SiO_2.2\ H_2O$	Am	$2\cdot3-2\cdot4$	$2-2\cdot5$
25	Rowlandite	Y silicate contg. Ce,La,Th		$4\cdot51$	6
26	Rubellite	Tourmaline (q.v.)			
27	Rubicelle	Spinel (q.v.)			
28	Ruby, Almandine	Spinel (q.v.)			
29	— Balas	Spinel (q.v.)			
30	— Oriental	Al_2O_3	III.rh.	$3\cdot90-4\cdot16$	9
31	— Silver	See Pyrargyrite.			
32	— Spinel	Spinel (q.v.)			
33	Rutherfordite	(Ce,La,Di) phosphate. Uncertain	?		
34	Rutile	TiO_2	II.	$4\cdot18-4\cdot22$	$6-6\cdot5$
35	Safflorite	$(Fe,Co)As_2$	IV.		$3-3\cdot5$
36	Sagenite	SiO_2 penetrated by long acicular crystals of Rutile.			
37	Sahlite	Augite contg. Fe			
38	Sal ammoniac	NH_4Cl	I.	$1\cdot52$	$1\cdot5-2\cdot0$
39	Salmiak	See Sal Ammoniac.			
40	Salt, Common	See Rock Salt.			
41	Saltpetre	See Nitre.			
42	Samarskite	$(Fe,Ce,Y,Er)_4(Nb_2O_7)_3.$ $(Fe,Ce,Y,Er)_6O+$ $5\ UO_3$	IV	$5\cdot6-5\cdot8$	$5\cdot5-6$

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
	P.Br.					1
Met.	Y.W.	Shining		Fus.	s. HNO_3+HCl	2
Vit.	W., Gr., Y., G.					3
Vit.—py.	Rose R., Y.Gr., Br.	W.	Uneven, brittle	Inf.	s. warm HCl	4
Vit.	FleshR.,Br.R., G., Y., Bl.	W.	Uneven, conch.	Fus. 2·5	Ins. HCl	5
	W.					6
						7
	Cream Y.					8
Vit.	Bl.	?	∞P 124°	E. fus.		9
Vit.	Y., Br.Y.	?	∞ P ō̄	Fus.	s. HCl with sepn. of powderySiO_2	10
Py.	G., Y., W., R., V.	W.	Conch.	Fus.	Decom. H_2SO_4	11
	Y.G.	Pale G.				12
						13
water)	W.		Earthy, like chalk			14
						15
Vit.	C., W., P., Y., Purple	C.	Conch.	Fus.	s. H_2O	16
						17
Vit.	Y.	Y.				18
	Br.G.					19
Vit.	R.	?		Fus.	s. HCl	20
	P.			Fus.	Gelatinous SiO_2 with HCl	21
Vit.	Rose P.	R.	Conch.	Inf.	s. HF	22
Vit.	Y.Br.—R.Br.	Br.	Conch.	3		23
Dull	G.		Earthy			24
Vit.	B.G.	?	Conch.	Inf.	Gelatinous SiO_2 with HCl	25
	R.					26
	Orange R.					27
	Violet					28
	Rose R.					29
Vit.	R.		Conch., uneven	Inf.	Ins.	30
						31
	Ruby R.					32
Vit. res.	Bl.Br.					33
Sub-met. ad.	R.Br.—R.—Bl.	Pale Br.	Conch.	Inf.	s.H_2SO_4+HF	34
	Tin W.	W.				35
						36
Coarse, dull	G.					37
Vit.	W., Y., Gr.	W.	Conch.	Sublimes	E.s. H_2O	38
						39
						40
						41
Sub-met.	Velvet Bl.	Dark R.Br.	Conch.	D. fus.	D.s. HCl	42

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Sanidine	Glassy Orthoclase	V.	2·39—2·62	6
2	Sapphire, True	Al_2O_3	III.rh.	3·90—4·16	9
3	— Brazilian	Tourmaline (q.v.)			
4	Sapphirine	5 MgO.6 Al_2O_3.2 SiO_2	V.	3·5	7·5
5	Sarcolite	3 $(Ca,Na)_2O.4 Al_2O_3$. 3 SiO_2	II.pyr.h.	2·5—2·9	6
6	Sardonyx	Chalcedony. (Flat-banded variety, composed of blue			
7	Sassoline	3 $H_2O.B_2O_3$	VI.	1·48	1
8	Satin Spar	Compact fibrous variety of calcite, like satin or fibrous variety of gypsum.			
9	Saussurite	Impure Labradorite		3·25—3·38	7
10	Scapolite	4 CaO.3 Al_2O_3.6 SiO_2 or 2 $Na_2O.Al_2O_3$. 9 SiO_2 with Cl	II.	2·6—2·8	5—6
11	Scheelite	$CaWO_4$	II.h.	5·9—6·075	4·5—5
12	Schiller Spar	Alteration product of enstatite or bronzite		2·5—2·7	3·5—4
13	Schorl	Tourmaline (q.v.)			
14	Schorlomite	3 $(Ca,Fe)O. 4 Al_2O_3$. 15 SiO_2 with Ti		3·80	7—7·5
15	Schwatzite	Mercuriferous Tetrahedrite.			
16	Scolecite	$CaO.Al_2O_3.3 SiO_2$. 2 H_2O	V. or VI.	2·24—2·26	5—5·5
17	Scorodite	$FeAsO_4.2 H_2O$	IV.	3·1—3·3	3·5—4
18	Selenide, Copper (Berzelianite)	Cu_2Se	?	6·71	2·5—3
19	— Copper Lead (Zorgite)	$(Pb,Cu_2)Se$		7—7·5	1
20	— Lead (Clausthalite)	PbSe	I.	8·2—9·0	2·5—3
21	— Mercury (Tiemannite)	HgSe	I.tetr.h.	8·19	2·5
22	— Silver (Naumannite)	Ag_2Se	I.	8	2·5
23	Selenite.	See Gypsum.			
24	Sellaite	MgF_2	II.	2·97—3	5
25	Selwynite	See Ochre, Yellow			
26	Semiopal	SiO_2			
27	Senarmontite	Sb_2O_3	I.	5·2	2—2·5
28	Sepiolite	2 MgO.3 SiO_2.2 H_2O	Am.	<1	2—2·5
29	Sericite	Flaky Muscovite.		2·8	
30	Serpentine	2 $H_2O.3(Mg,Fe)O$. 2 SiO_2	IV.	2·5—2·7	3—4
31	Seybertite	$6(Fe,Ca)O.9(Fe,Al)_2O_3$. 5 $SiO_2.\frac{1}{2} H_2O$	V.	3	4·5
32	Siderazote	Fe_5N_2 (Incrustation on Mount Etna.)			
33	Siderite	$FeCO_3$	III.rh.	3·7—3·9	3—4·5
34	Silica.	See Quartz.			
35	Silicate, Copper	See Chrysocolla.			
36	— Manganese	See Rhodonite.			
37	— Nickel	See Garnierite, Genthite.			
38	— Zinc	See Willemite, Hemimorphite.			
39	Siliceous Sinter	SiO_2 deposited round geysers.			
40	Silicified Wood	Fibrous material of vegetation replaced by silica.			

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit.	C.	C.	Conch.	Fus.		1
Vit.	B.		Conch.	Inf.	Ins.	2
	Berlin B., tr.					3
Vit.	W.B.		Uneven	Inf.	Ins.	4
Vit.	P., P.W.		Conch.	Fus.	Gelatinous SiO_2 with HCl	5
and white or	red and white layers.)					6
Py.	W., Gr., Y. tl.-tr.	W.	Sectile and flexible	1	s. H_2O and C_2H_5OH	7
						8
						9
Vit. py. res.	W., B., G., P. tr.-op.	C.	Sub-conch., brittle	Fus.	Part decomp. HCl	10
Vit.	Y.W., Br., Or.Y.	W. tr.	Uneven, brittle	5	s. HCl with sepn.of WO_3	11
Met. py.	G., G.Bl., Br.					12
	Bl. op.					13
	Bl.	Gr.Bl.		E. fus.	E. decomp. ac. with sepn. of gel. SiO_2	14
						15
Vit. or py.	W., Y., Gr., R.			Fus.		16
Vit.	G., B., Br.	W.G.	Uneven	2—3	s. HCl	17
Met.	Gr.	Gr.	Earthy	Fus.	s. HNO_3	18
Met.	Gr.	Gr.	Friable	1	s. HNO_3	19
Met.	Gr.	Gr.	$\infty O \infty$	Inf.	s. HNO_3	20
Met.	Gr.	Gr.Bl.	Conch., uneven	E. fus. vol.	s. $HNO_3 + HCl$	21
Met.	Gr.Bl.	Bl.	$\infty O \infty$	Fus.	s. fuming HNO_3	22
Py.	W.					23
Vit.	C.		$\infty P \infty$	E. fus.	Decom. H_2SO_4	24
						25
	W., tl.					26
Ad. greasy	C., W., Gr.		Uneven	Fus. vol.	s. HCl	27
Soapy	W., Gr.W., Y., P.	W.	Earthy		Gelatinous SiO_2 with HCl	28
Sy.	G., Y.W.					29
Res. soapy	G.Gr., Br.	G.W.	Conch., fibrous	5·5		30
Py. sub-met.	R.Br., Y.Br., Copper R.	Br.	Foliated			31
Steel-like						32
Py.	Gr.W.—Br.—R.	C.	Conch.	Inf.	s. hot HCl	33
						34
						35
						36
						37
						38
						39
						40

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Silver Amalgam	$AgHg_2$	I.	10·5—14	3—3·5
2	— Glance	See Argentite.			
3	— Lead Ore	PbS (argentiferous)	I.		
4	— Native	Ag	I.	10·1—11·1	2·5—3
5	Sinter, Iron	See Scorodite. (Amorphous variety.)			
6	Sipylite	$(Y,Er)NbO_4$ with Ce	II.	4·88—4·89	5·5—6
7	Smaltine	$CoAs_2$	I.	6·4—7·2	5·5—6
8	*Smithsonite	$2 ZnO.SiO_2 + H_2O$	IV.	3·16—3·49	4·5—5
9	Soapstone	See Talc.			
10	Sodalite	$3 NaAlSiO_2 + NaCl$	I.	2·13—2·26	5·5—6
11	Soda Nitre	$NaNO_3$	III.rh.	2·09—2·29	1·5—2
12	Spartalite	ZnO	III.	5·4—5·7	4—4·5
13	Spathic Iron Ore	See Chalybite.			
14	Spear Pyrites	See Marcasite.			
15	Specular Iron	See Red Hematite.			
16	Spessartite	See Garnet, Manganese-Alumina.			
17	Sphalerite	See Blende, Zinc.			
18	Sphene	$CaO.TiO_2.SiO_2$	V.	3·4—3·56	5—5·5
19	Spinel	$MgO.Al_2O_3$	I.	3·5—3·6	8
20	— Ruby	See Spinel.			
21	Spodumene	$Li_2O.Al_2O_3.4 SiO_2$	V.	3·13—3·19	6·5—7
22	Stannine	$2 Cu_2S.(Fe,Zn)S.SnS_2$	I.tetr.	4·3—4·5	1
23	Staurolite	$H_2O.2 FeO.5 Al_2O_3. 4 SiO_2$	IV.	3·4—3·8	7—7·5
24	Staurotide	See Staurolite.			
25	Steatite	See Talc.			
26	Stephanite	$5 Ag_2S.Sb_2S$	IV.	6·26	2—2·5
27	Sternbergite	$(Ag_2,Fe)S$		4·215	1·5—2
28	Stibnite	See Antimony Blende.			
29	Stilbite	$(Na_2,Ca)O.Al_2O_3. 6 SiO_2.6 H_2O$	V.	2—2·2	3·5—4
30	Stilpnomelane	$2 FeO.SiO_2$ with Al, Ca,Mg, etc.	?	3—3·4	3—4
31	Stinkstone	See Anthraconite.			
32	Stolzite	$PbWO_4$	II.	7·9—8·1	2·5—3
33	Strengite	$FePO_4.2 H_2O$	IV.	2·8—2·91	3—4

*This is taken as the English name, and is the "Calamine" of Dana.

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Met.	Silver W. op.	W. op.	Brittle conch., uneven	Fus., Hg vol.	s. HNO_3	1
						2
Met.	Gr.W.	Gr.		E. fus.	s. HNO_3	3
Met.	Silver W.	W., shining	Sectile, malleable	Fus.	s. HNO_3	4
						5
Met. res.	Br.Bl.	Br.Gr.	Conch., uneven	Inf.		6
Met.	Tin W.—Gr.	Gr.Bl.	Granular, brittle	Fus. As_2O_3 vol.	s. HNO_3 with sepn. of As_2O_3	7
Vit. subpy.	W., Y., Br., G., B.	W.	Brittle	Very d. fus.	s. conc. KOH soln.	8
						9
Vit.	Gr., B., Y., &c.	C.	Conch., uneven	3·5	Gelatinous SiO_2 with HCl or HNO_3	10
Vit.	W., Gr., Y., R.Br.	C.	Conch.	Fus.	s. H_2O	11
Sub-ad.	Deep R.	OrangeY	Brittle	Inf.	s. ac.	12
						13
						14
						15
						16
						17
Ad. or res.	Br.,Gr., Br.Gr., Y., G., Bl.	W.	Imperfect conch., brittle	5	Decom. H_2SO_4	18
Vit.	R., Br., Bl., G., B.		Conch.	Inf.	D.s. conc. H_2SO_4	19
						20
Py.—vit.	Gr.G. tl.—stl.	C.	Uneven	3·5	Ins.	21
Met.	Steel Gr., Bl., Bronze	Bl.	Uneven, brittle	D. fus.		22
Subvit.-res.	R.Br., Br.Bl., Y.Br.	C. or Gr.	Conch.	E. fus.(Mn) or Inf. (Fe)	Ins.	23
						24
						25
Met.	Iron Bl.	Bl.	Uneven	Fus.	s. HNO_3 with sepn. of S and Sb_2O_3	26
Met.	Pinchbeck Br.	Bl.	Like graphite	E. fus.	s. HNO_3	27
						28
Py. vit.	W., Y., Br., R.	C.	Conch.	Fus.		29
Vit. greasy	B., G.Bl.	G., G.Gr.	Regular	Fus.	D. decomp. HCl	30
						31
Res	G., Gr., Br., R.		Conch.	E. fus.	s. HNO_3 with sepn.of WO_3 .S.KOH	32
Vit. py.	C., P.		Imperfect conch.	E. fus.	E.s. HCl, Ins. HNO_3	33

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness
1	Stromeyerite	$Ag_2S + Cu_2S$		6·26	2·5—3
2	Strontianite	$SrCO_3$	IV.	3·6—3·8	3·5
3	Struvite	$(NH_4)MgPO_4 + 6 H_2O$	IV. (h.)	1·66—1·75	1·5
4	Succinite	See Garnet, Lime-Alumina.			
5	Sulphate, Aluminium	See Aluminite, Alunogene.			
6	— Ammonium	See Mascagnine.			
7	— Barium	See Barytes.			
8	— Calcium	See Anhydrite, Gypsum.			
9	— Cobalt	See Bieberite.			
10	— Copper	See Chalcanthite.			
11	— Iron	See Copperas.			
12	— Lead	See Anglesite.			
13	— Magnesium	See Epsom Salt.			
14	— Nickel	See Morenosite.			
15	— Sodium	See Glaubersalt, Thenardite.			
16	— Strontium	See Celestine.			
17	— Uranium	See Uranvitriol.			
18	— Zinc	See Goslarite.			
19	Sulphide, Antimony	See Antimony Blende.			
20	— Arsenic	See Realgar, Orpiment.			
21	— Bismuth	See Bismuthine.			
22	— Cadmium	See Greenockite.			
23	— Cobalt	See Linnæite.			
24	— Copper	See Bornite, Copper Pyrites.			
25	— Iron	See Iron Pyrites.			
26	— Lead	See Galena.			
27	— Manganese	See Alabandin			
28	— Mercury	See Cinnabar.			
29	— Molybdenum	See Molybdenite.			
30	— Nickel	See Millerite.			
31	— Silver	See Argentite.			
32	— Tin	See Stannine.			
33	— Zinc	See Sphalerite.			
34	Sulphur, Native	S	IV.	2·07	1·5—2·5
35	Sunstone	Orthoclase (q.v.) [translucent with minute spangles			
36	Sussexite	$(Mg,Mn)B_4O_7.aq$	?	3·42	
37	Sylvanite	See Graphic Tellurium.			
38	Sylvine	KCl	I.	1·9—2	2
39	Tabular Spar	See Wollastonite.			
40	Tachyhydrite	$CaCl_2.2 MgCl_2.12 H_2O$	III.rh.	1·9—2	2
41	Talc	$H_2O.3 MgO.4 SiO_2$	IV.	2·5—2·8	1 (1·5)
42	Tantalite	$(Fe,Mn)O.(Nb,Ta)_2O_5$	IV.	7—8	6—6·5
43	Tapiolite	$FeO.(Nb,Ta)_2O_5$	II.	7·3—7·5	6
44	Tarapacaite	K_2CrO_4			
45	Telluric Bismuth	$Bi_2(S,Te)_3$	III.	7·2—7·9	1·5—2
46	—Ochre	TeO_2	Am.		
47	Telluride, Gold	$AuTe_2$		9·043	1·5—2
48	— Lead	See Nagyagite.			
49	— Silver	See Tellurium, Graphic.			
50	Tellurium, Foliated	See Nagyagite.			
51	— Graphic	$(Ag, Au)Te_2$	V.	7·9—8·33	1·5—2·0

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Met.	Steel Gr.	Gr.	Conch.	Fus.	s. HNO_3	1
Vit.	C., W., Y., P.		Conch., uneven	5	s. HCl	2
Vit. res.	C., Y. Amber Y.		oP, $\infty P \infty$			3
						4
						5
						6
						7
						8
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						31
						32
						33
Res.	Sulphur Y. or tinted G. or Or.	Y.	Sectile; very brittle	E. fus.	Ins.	34
of mica disseminated thr	oughout]					35
Py.	W., P., Y.		Fibrous			36
						37
Vit.	W., C., P., Y.		$\infty O \infty$	2	E.s. H_2O	38
						39
Vit.	C., Y., W.	C.		1	s. H_2O	40
Py.	W., G., Gr., Gr.G.	W., Gr.G.	Foliated	6	Ins.	41
Ad., met., greasy	Gr.Bl.	Bl.Br.	Conch., uneven	Inf.	Ins.	42
Met.	Bl.	Bl.		D. fus.	Ins.	43
Vit. res.	Y., Or.	Y.				44
Splendent met.	Pale steel Gr.	Gr.Bl.	$_0$R	1	s. HNO_3 with sepn. of S.	45
Earthy	W., Y.	W.Y.	Earthy		Ins.	46
						47
Met.	Y. (Bronze)	Y.W.				48
						49
Met.	Steel Gr.— silver W.	Gr.W.	$\infty P \infty$	Fus.	s. HNO_3 with sepn. of Au	50
						51

	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Tellurium, Native	Te	III.rh.	6·1—6·3	2—2·5
2	Tennantite	4 $Cu_2S.As_2S_3$ with Fe	I.	4·5—4·9	4
3	Tenorite	CuO	Am. or VI.	6·25	3
4	Teratolite	Fe_2O_3, Mn_2O_3+ decomp. Felspar	Am.	2·5	2·5—3
5	Tetradymite	See Telluric Bismuth.			
6	Tetrahedrite	4 $Cu_2S.Sb_2S_3$	I.	4·5—5·1	3—4·5
7	Thalenite	2 $Y_2O_3.4 SiO_2.H_2O$	V.	4·23 (R.) 4·11—4·16 (Y.)	6·5
8	Thenardite	Na_2SO_4	IV.	2·7	2·5
9	Thermonatrite	$Na_2CO_3.H_2O$	IV.	1·6	1·5—2
10	Thomsenolite	$NaF.CaF_2.AlF_3.H_2O$	V.		
11	Thomsonite	2 $(Ca,Na_2)O.2 Al_2O_3.$ 4 $SiO_2.5 H_2O$	IV.	2·3—2·4	5—5·5
12	Thorite	ThO_2,SiO_2 contg. (Ca,Fe,Mn,U	II.	4·4—4·7	4·5
13	Thulite	Zoisite (q.v.)			
14	Thuringite	4 $(Al,Fe)_2O_3.7 FeO.$ 6 $SiO_2.9 H_2O$	Am.	3·15—3·20	2—2·5
15	Tiemannite	HgSe			
16	Tile Ore	See Cuprite.			
17	Tincal	See Borax.			
18	Tin Stone	See Cassiterite.			
19	— Pyrites	See Stannine.			
20	Titanic Iron	See Ilmenite.			
21	Titanite	$CaO.TiO_2.SiO$	V.	3·4—3·56	5—5·5
22	Topaz	$Al_2O_3.SiO_2$	IV.	3·4—3·65	8
23	— False	SiO_2 (quartz)	III.rh.	2·5—2·8	7
24	— Oriental	Corundum (q.v.)			
25	Topazolite	See Garnet, Iron-lime.			
26	Torbanite	Variety of Cannel, remarkable for high ash			and
27	Torbernite	$(CuO+2 U_2O_3)P_2O_5+$ 8 H_2O	(See Chalcolite.)		
28	Touchstone	See Lydian Stone.			
29	Tourmaline	4 $(Li, Na)_2O . 4 FeO .$ 6 $B_2O_3 . 15 Al_2O_3 .$ 24 $SiO_2 7 H_2O$. (Li variety). Also Fe and Mg varieties.	III.rh.	2·9—3·3	7—7·5
30	Traversellite	Augite with little Al_2O_3	Long fibrous crystals		

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Met.	W.	Tin W.	Imperfect	E. fus.	Oxidised by HNO$_3$ to H$_2$TeO$_3$	1
Met.	Lead Gr.—Iron Bl.	Gr.Bl.	Uneven	Fus.	s. HNO$_3$ with sepn. of S. and As$_2$O$_3$	2
Dull	Bl.	Bl.Br.	Earthy	Inf.	s. ac.	3
Dull	B.	?	Uneven, fine earth			4
						5
Met.	Steel Gr.—Iron Bl.	Gr.Bl.	Uneven, sub-conch., rather brittle	Fus.	s. HNO$_3$ with sepn. of S., As$_2$O$_3$ and Sb$_2$O$_3$	6
Greasy	R.Y		Uneven, splintery(R.) conch. (Y.)			7
Vit.	C.W.P.	W.	Uneven	Fus.	E.s. H$_2$O	8
Vit.	C.		∞P$\bar\infty$	E. fus.	s. H$_2$O	9
Py.	C.		oP	E. fus.		10
Vit.	C., W., Gr.,Y., P., G.		∞ P $\bar\infty$	2	Gelatinous SiO$_2$ with HCl	11
Vit.	Y.Br.	Y.	Conch., splintery	Inf.	Gelatinous SiO$_2$ with HCl	12
	R.					13
Py.	G., Y.	G.Gr.	Scaly	E. fus.	Gelatinous SiO$_2$ with HCl	14
Met.	Steel Gr.—Bl.	Gr.Bl.		E. fus.		15
						16
						17
						18
						19
						20
Ad.—res.	Gr.Br., Br.—Bl. (Y.—G.)	C.	Conch.	Fus.	Part. decomp. HCl	21
Vit.	Pale Y., W., G., B., R.	W.	Conch.	Inf.	Ins.	22
Vit.	Lemon Y.		Conch.	Inf.	s. HF	23
	Y.					24
	Wine Y.					25
large % gaseous hydrocarbons						26
						27
						28
Vit.	Bl., B.Bl., B., Gr., R.	C.	Sub-conch. or uneven, brittle	5·5—6		29
			Asbestiform			30

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	Name.	Composition.	Cryst. System.	Specific Gravity.	Hardness.
1	Tremolite	$3\,MgO.SiO_2 + CaO.SiO_2$		$2\cdot9{-}3\cdot1$	$5{-}6\cdot5$
2	Tridymite	SiO_2 (quartz)		$2\cdot28{-}2\cdot33$	(Occurs
3	Tripestone	Anhydrite (q.v.) (Con	cretionary)		
4	Triphylite	$Li(Fe,Mn)PO_4$	IV.	$3\cdot54{-}3\cdot6$	5
5					
6	Triplite	$(Fe,Mn)_2FPO_4$	V.	$3\cdot5{-}3\cdot8$	$5\cdot5$
7	Tripolite	SiO_2	(Secretions	of microsco	pic
8	Trippkëite	$CuAs_2O_4$	II.		
9	Trögerite	$(UO_2)_3As_2O_8.8\,H_2O$	V.	$3\cdot23$	
	Trona	$Na_2CO_3.NaHCO_3.$ $2\,H_2O$	V.	$2\cdot11$	$2\cdot5{-}3$
10	Troostite	$2\,(Zn,Mn)O.SiO_2$	III.rh.t.	$3\cdot89{-}4\cdot29$	$5\cdot5{-}6$
11	Tschermigite	See Alum, Ammonium.			
12	Tufa	$CaCO_3$—water deposit	ed.		
13	Tungstate, Iron	See Wolfram.			
14	— Lead	See Stolzite.			
15	— Lime	See Scheelite.			
16	Tungstic Ochre	WO_3	Am.	$6\cdot3{-}7\cdot2$	Soft
17	Tungstite	See Tungstic Ochre.			
18	Turquois	$Al_2O_3.P_2O_5+5\,H_2O$	Am	$2\cdot6{-}2\cdot8$	6
19	Tyrolite	See Copper froth.			
20	Tysonite	$(Ce,La,Di)F_3$	III.		Soft
21	Ulexite	$NaCaB_5O_9.8\,H_2O$	Am.	$1\cdot65$	1
22	Ullmannite	$NiSbS$	I. pent.	$6\cdot1{-}6\cdot5$	$5{-}5\cdot5$
23	Ultramarine	See Lapis Lazuli.			
24	Uraconite	See Uranic Ochre.			
25	Uralite	Amphibole		$3\cdot15$	
26	Uranic Ochre	U_3O_8 mainly, contg. Ra	Am.		Soft
27	Uraninite	See Pitchblende.			
28	Uranite, Copper	See Torbernite.			
29	— Lime	See Autunite.			
30	Uranospherite	$U_2O_7(BiO)_2.3\,H_2O$ contg. Ra		$6\cdot36$	$2{-}3$
31	Uranvitriol	USO_4 contg. Cu	V.	$3\cdot19$	$2{-}2\cdot5$
32	Uwarowite	$6\,CaO.3\,SiO_2 + 2\,Cr_2O_3.3\,SiO_2$	I.	$3\cdot42$	$6\cdot5{-}7\cdot5$
33	Valentinite	Sb_2O_3	IV.	$5\cdot4{-}5\cdot62$	$2\cdot5{-}3$
34	Vanadinite	$9\,PbO.3\,V_2O_5.PbCl_2$	III. pyr.	$6\cdot6{-}7\cdot1$	3
35	Variscite	$Al_2O_3.P_2O_5.$ aq	Am.		
36	Vanquelinite	$2\,PbO.CuO.2\,CrO_3$	V.	$5\cdot5{-}5\cdot8$	$2\cdot5{-}3$
37	Vermiculite	$3\,MgO.(Fe,Al)_2O_3.$ $3\,SiO_2$	?		
38	Vermilion	See Cinnabar.			
39	Vesuvianite	See Idocrase.			
40	Vitreous Copper Ore	See Redruthite.			
41	— Silver Ore	See Argentite.			
42	Vitriol, Blue	See Chalcanthite.			
43	— Green	See Copperas.			
44	— White	See Goslarite.			
45	Vivianite	$3\,FeO.P_2O_5.8\,H_2O$	V.	$2\cdot58{-}2\cdot68$	$1\cdot5{-}2$

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
Vit.	W.—dark Gr.		Conch. or Fibrous	4	Ins.	1
in triple he	xagonal plates	in trach	yte.)			2
						3
Subres.-	Gr.G.—B.Gr., Br.Bl.	Gr.W.	oP	1·5	s. HCl	4
Greasy	Br.	Gr.G.		E. fus.	s. HCl	5
diatoms, he	nce "Diatomit	e.)				6
Met.	B.G.	?	∞P ∞, ∞P	E. fus.	E.s. HCl.	7
	Y.	?	∞P ∞̃			8
Vit.	C., Gr., Y.W.	?		Gives H_2O and CO_2	s. ac. and H_2O	9
Vit.·greasy	G., Y., R.Br. Gr.	Y.		6	Gelatinous SiO_2 with HCl	10
						11
						12
						13
						14
						15
Dull sy.	Bright Y.— Y.G.	?	Pulverulen t	Inf.	s. alk.	16
						17
Wax.	Turquois B.— B.G.	W.	Conch.	Inf.	s. HCl	18
						19
Wax.	Y.Br.	W.Y.	Conch.	Fus.		20
Dull	W.	W.	Powdery	Fus.	Part s. H_2O	21
Met.	Gr.Bl.	Gr.Bl.	Uneven	1	s. aqua-regia	22
						23
						24
Py.	Bl.G.	Gr.G.	Fibrous	4	Decomp. ac.	25
	Lemon Y., Or.	Y.	Pulverulent			26
						27
						28
						29
Dull	R., Orange	?	Scaly	Inf.	Ins.	30
Vit.	G.	G.	∞P		D.s. H_2O	31
Vit.	G.		Conch.	Inf.	Ins.	32
Ad. py.	W., Y., Gr.		∞P ∞̆	1	E.s. HCl	33
Greasy	Y., Br., R.		Uneven	E. fus.	E.s. HNO_3	34
Dull	Light G.— emerald G.	G.W.				35
Py.	Dark G.— Py.Bl.	Y.Gr.		E. fus.	s. HNO_3 with Y. ppt.	36
Py.	Gr., Br.,Y., Br.		Mica-like	D. fus.	Ins.	37
						38
						39
						40
						41
						42
						43
						44
Py.—vit.	B.—G. W.	B.	Conch.	E. fus.	s. HCl	45

	Name.	Composition.	Cryst. System.	Spécific Gravity.	Hardness.
1	Volborthite	$\frac{1}{4}(Cu,Ca)O.V_2O_5.H_2O$	IV. ?	3·49—3·55	3·5
2	Voltaite	$2(Fe,Al)_2O_3.5(Mg,Fe, Na_2,K_2)(OH)_2.(SO_4).$ 14 H_2O	II. ?	2·6—2·79	3·5
3	Voltzite	$4 ZnS + ZnO$	Am.		
4	Vulpinite	Anhydrite (q.v.)	Am.		
5	Wad	MnO with BaO & H_2O	Am.	3—4·26	0·5—6
6	Wagnerite	$Mg(MgF)PO_4$	IV.	3·1	5—5·5
7	Warringtonite	See Brochantite.			
8	Wavellite	$3 Al_2O_3.2 P_2O_5 + 12 H_2O$	IV.	2·33	3·5—4
9	Websterite	$Al_2SO_6.9 H_2O$	Am.	1·66	Soft
10	Wernerite	See Scapolite.			
11	White Arsenic	See Arsenic, White			
12	— Lead Ore	See Cerussite.			
13	— Nickel	See Chloantite.			
14	— Vitriol	See Goslarite.			
15	Willemite	$2 ZnO.SiO_2$	III. ·h.	4—4·1	5—5·5
16	Witherite	$BaCO_3$	IV.	4·29—4·35	3—3·75
17	Wöhlerite	$5 Na_2O.20 CaO. 2Nb_2O_5.20 SiO_2.3 ZrO_2$ with other oxides and F	V.	3·41	5—6
18	Wolfram	$(Fe,Mn)WO_4$	V.	7·1—7·9	5—5·5
19	Wolframine	See Tungstic Ochre.			
20	Wollastonite	$CaO.SiO_2$	V.	2·7—2·9	4·5—5
21	Wood Opal	SiO_2 replacing fibres of wood.			
22	Woodwardite	$CuSO_4.Al_2(SO_4)_3.$ aq			
23	Wulfenite	$PbMoO_4$	II.	6·03—7·01	2·75—3
24	Xanthophyllite	$\frac{1}{4}H_2O.14(Mg,Ca)O. 8(Al,Fe)_2O_3.5 SiO_2$	V.	3—3·1	4·5—5·
25	Xenotime	$(Y,Ce,Er)PO_4$	II.	4·45—4·55	4·5—5
26	Yenite	Lièvrite (q.v)			
27	Yttrialite	$Y_2O_3.2 SiO_2$ with Th Fe		4·57	5—5·6
28	Yttrocerite	$(Y,Er,Ce)F_3.5CaF_2. H_2O$		3·3—3·4	4—5
29	Yttrotantalite	$Y_4(Ta_2O_7)_3$ contg. He		5·2—5·9	5·5
30	Yttrotitanite	$CaO.TiO_2.SiO_2. Y,AlFe)_2O_3.SiO_2^{..}$	IV. V.	3·51—3·72	6—7
31	Zaratite	See Emerald Nickel			
32	Zincite	ZnO.		5·68—5·74	4—4·5
33	Zinkenite	$PbS.S_2Sb_6$	III. IV.	5·30—5·35	2—2·5
34	Zinnwaldite	$\frac{1}{4}(Na,Li,K)F. 10 SiO_2. Fe_2O_3.3Al_2O_3. (Na,Li,K)_2O$	V.	2·909	2—2·5
35	Zippeite	$U_3(SO_4)_3$ with <5% CuO	IV.		
36	Zircon	$ZrSiO_4$	II.	4·7	7·5

Lustre.	Colour.	Streak.	Fracture.	Fusibility.	Solubility.	
	Y., G.	Y.	Earthy	Fus.	s. HNO_3	1
Py. vit.	Bl.G.	G.Gr.	Uneven			2
Py.	Dirty-rose R.	P.	Implanted globules			
			Scaly			4
Dull	Bl., B., Gr.,Br.	Gr.Br.	Earthy	Inf.	s. HCl	5
Vit.	Y.—Gr.		Imperfect conch.	D. fus.	Ins.	6
						7
Vit. py. res.	W., Y., Br.	W.	Brittle, spherular	Inf.	s. warm HCl	8
Dull	W.	W.	Earthy			9
						10
						11
						12
						13
						14
Vit.	W., Y., Br.	W.	Conch.	Inf.	Ins.	15
Vit. res.	W., Y., Gr.	W.	Brittle	Inf.	s. ac.	16
Greasy	Y., B., G.			Fus.	Decomp. HCl with sepn. of SiO_2 and Nb_2O_5	17
Met.—dull	Gr.Bl.	R.Br.	Uneven	Fus.	s. H_2SO_4	18
						19
Vit. py.	W., Gr., Y., P., Br.	W.	Tough	½	Ins.	20
						21
	Turquois B.					22
Wax. ad.	Y., Or., Gr., W., Br.	W.	Brittle	Fus.	Decomp. HCl	23
Vit. py.	Y., G., C.		oP	Inf.	Decomp HCl with sepn. of SiO_2	24
Greasy	R.Br., Y.Br., R., Y.	Y.W., P.	∞P	Inf.	Ins.	25
						26
	Y., Y.Gr.			Inf.	E.s. HCl	27
	B.Gr., B.W.					28
Met. vit.	Bl., G.	Gr.	Conch.	Inf.	Ins.	29
Vit.	Br.R., Br.	Gr.Y.		Inf.	s. HCl	30
						31
Sub-ad.	Bright R.	Or.Y.	Laminated	Inf.	s. HNO_3	32
Met.	Gr.	Gr.		Fus.	s. HNO_3 with sepn. of S and Sb_2O_3	33
Py.	G.	W.	Micaceous	1		34
	G.Y.	Y.W.				35
Ad.	C., Gr., Y., G., R.Br.	C.	Conch.	Inf.	Ins.	36

GENERAL PROPERTIES OF INORGANIC

If water of crystallisation in ( ),
Salts of Organic Acids will be found

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Alum, ammonium	$Al_2(SO_4)_3(NH_4)_2SO_4+24\,H_2O$	907.1	1.6357/0°
2	— chrome	$Cr_2(SO_4)_3K_2SO_4+24\,H_2O$	998.9	1.83
3	— iron	$Fe_2(SO_4)_3(NH_4)_2SO_4+24\,H_2O$	964.4	1.712
4	— potash	$Al_2(SO_4)_3K_2SO_4+24\,H_2O$	948.9	1.751/17°
5	— silver	$Al_2(SO_4)_3Ag_2SO_4+24\,H_2O$	1086.5	
6	— sodium	$Al_2(SO_4)_3Na_2SO_4+24\,H_2O$	916.7	1.675/20°
7	Aluminium	Al	27.0	2.583
8	— bromide	$Al_2Br_6(+12\,H_2O)$	533.5	2.54
9	— carbide	Al_4C_3	144.0	2.36
10	— chloride	$Al_2Cl_6(+12\,H_2O)$	266.8	D :9.34/400° 4.51/835°
11	— fluoride	Al_2F_6	168.0	3.1
12	— hydroxide	$Al_2(OH)_6$	156.0	2.28
13	— iodide	$Al_2I_6(+12\,H_2O)$	815.5	2.63
14	— nitrate	$Al_2(NO_3)_6+18\,H_2O$	750.4	
15	— nitride	AlN	41.0	
16	— oxide	Al_2O_3	102.0	3.75—4.0
17	— phosphate	$Al_2(PO_4)_2$	244.1	2.59
18	— sulphate	$Al_2(SO_4)_3$	342.2	2.74
19	— sulphate	$Al_2(SO_4)_3+18\,H_2O$	666.6	1.69
20	— sulphide	Al_2S_3	150.2	2.37
21	Ammonia	NH_3	17.03	liq. : 0.6234

Notes.—s. soluble; i. insoluble; v.s. very soluble; s.s. slightly soluble; v.s.s. very slightly soluble; m. miscible in all proportions; c. cold; h. hot; alc. alcohol; alk. alkalies; ac. acids; liq. liquid; gas. gaseous; $>H_2O$, $<H_2O$, heavier, lighter than water; d. decomposed; an. anhydrous. In the fourth column, D. represents the density of the gaseous form. In column nine, the sign aq., 2aq., 3aq., with a temperature signifies that the compound loses 1, 2, or 3 molecules of

COMPOUNDS. (See also "Properties of Minerals.")
not included in formula weight.

in the Tables of Organic Compounds.

Crystalline form and colour	Solubility* in			M.P. °C.	B.P. °C.	
	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies			
I. C.	11.4	421.9	i. alc.			1
I. R.	15	green at 70°	i. alc.	22aq 200 24aq 400		2
I; Viol.	14.3(20°)	400	i. alc.	24aq 230		3
I. C.	9.6	357.5		84.5	1?? 60	4
	d.				1aq R.H.	5
I.	110	v.s.	i. alc.	24aq 50		6
B.W.	i.	i.	s. alk., HCl, H_2SO_4	658.7		7
C.	s.	s.	s. alc., CS_2	93	263	8
G. cryst.	gives CH_4					9
III.	s.	loses HCl	s. alc.		182/752 mm.	10
IIIa. C.	an. i. +7aq. s.		i. alc., alk., 1o.			11
Am. W.	i.	.	s. ac., alk.	at 300 : $Al_2O_4H_2$		12
W.	an. i., +12aq. s.		s. alc., CS_2	185	360	13
	v.s.	v.s.	s. alc.	73	d. 134	14
Y. cryst.	d.			d. 135		15
III. Am.	i.	i.	s. H_2SO_4			16
III. C.	i.	i.	s. alk., ac., i. acetic			17
W.	35	89.1	s.s. alc.			18
V. C.	102	1132				19
Y. cryst.	d.			d.		20
	597 vols.	i.	v.s. alc.	-75	-33.5	21

water at that temperature. R.H. red heat; W.H. white heat;
C. colourless; W. white; R. red; P. pink; B. blue; Y. yellow;
G. green; Br. brown; Bl. black; Gr. grey; Viol. violet; L. lilac;
Or. orange; expl. explodes; diss. dissociates.

Crystal forms (see "Crystallography" section): I. cubic;
II. tetragonal; III. hexagonal; IIIa. rhombohedral; IV. rhombic;
V. monoclinic; VI. triclinic; Am. amorphous.

* Parts anhydrous substance unless otherwise stated.

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Ammonium aurichloride	NH_4AuCl_4	357.1	
2 — auricyanide	$Au(CN)_3NH_4CN+H_2O$	337.3	
3 — aurocyanide	$Au(CN)_2NH_4CN$	293.3	
4 — bicarbonate	NH_4HCO_3	79.05	1.586
5 — borofluoride	NH_4BF_4	105.0	1.851/17°
6 — bromide	NH_4Br	97.96	2.379/4° D :1.67/440°
7 — carbamate	$NH_4HCO_3+NH_4CO_2NH_2$	157.12	
8 — carbonate	$(NH_4)_2CO_3+H_2O$	114.1	
9 — chlorate	NH_4ClO_3	101.50	
10 — chloride	NH_4Cl	53.50	1.532
11 — chromate	$(NH_4)_2CrO_4$	152.08	1.886/11°
12 — chromic sulphate	$Cr_2(SO_4)_3(NH_4)_2SO_4+24H_2O$	956.71	1.736/21°
13 — cyanate	NH_4CNO	60.06	
14 — cyanide	NH_4CN	44.06	D :0.79/100°
15 — dichromate	$(NH_4)_2Cr_2O_7$	252.08	2.367
16 — ferricyanide	$2(NH_4)_3Fe(CN)_6+H_2O$	550.05	
17 — ferrocyanide	$(NH_4)_4Fe(CN)_6+3H_2O$	338.2	
18 — fluoride	NH_4F	37.0	
19 — hydrogen fluoride	$NH_4F HF$	57.0	1.210/12°
20 — — phosphate	$(NH_4)_2HPO_4$	132.13	1.803/20°
21 — — sulphide	NH_4HS	51.11	
22 — hypophosphite	$NH_4H_2PO_2$	83.10	2.515
23 — iodide	NH_4I	144.96	D :2.51/440°
24 — iridichloride	$(NH_4)_2IrCl_6$	456.0	
25 — magnesium arsenate	$Mg(NH_4)AsO_4+6H_2O$	289.42	
26 — — phosphate	$Mg(NH_4)PO_4+6H_2O$	245.5	1.65
27 — molybdate	$(NH_4)_6Mo_7O_{24}+4H_2O$	1236.3	2.498
28 — nitrate	NH_4NO_3	80.05	1.72/15°
29 — nitrite	NH_4NO_2	64.05	1.69
30 — palladichloride	$(NH_4)_2PdCl_6$	355.5	2.418

Crystalline form and colour	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
	v.s.	v.s.		an. at 100		1
Plates	s.		s. alk.	d.		2
C.	s.		s. alk.	d. 150—200		3
IV. W.	18.5	d.	i. alc.	d. 60		4
III. prism	25	100	s. alk.			5
I. C.	66	128	s.s. alc.	d.		6
W. cryst.	25	70 (65°)	d. by alc.		subl.	7
C.	100	d. 70—75°	s. alc.	d. 85°		8
V.	s.	s.	v.s.s. alc.	expl. 102		9
I. or II. C	35.2	77.3	v.s.s. alc.		diss. 350	10
V. Y.	40.5/30°	d.		d.		11
I. Oct.	12.1	green at 70°		18aq 100 22aq>106	.	12
	s.	d.	s.s. alc.	d.		13
I. C.	s.	d.	s. alc.		diss. 36	14
V. G.R.	47.2/30°	v.s.		d.toCr_2O_3		15
R. prism.	s.	s.				16
Y. prism.	v.s.	d.	i. alc.			17
III. C.	deliq.	v s.	s.s. alc.		subl.	18
IV. C.	deliq.	v.s.			diss.	19
V. C.	25	s.	i. alc.			20
IV. C.	s. 128.1 (0°)	s.	s. alc.	subl.		21
III. W. plates	s.	s.	v.s. alc.	200	d. 240	22
I.	deliq. 167	v.s.	s. alc.			23
R. pdr.	0.699	1.266 (39°)				24
II.	0.17	i.	i. alc.			25
II.	0.005	i.	i. alc.			26
IV. C.	40	s.		d.		27
IV.	106	v.s.	s. in 67% alc.	152	d. 210	28
W.	v.s.	d. 50°	d.			29
I. R.	s.s.	s.s.				30

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Ammonium perchlorate	NH_4ClO_4	117.50	1.87
2 — permanganate	NH_4MnO_4	136.97	
3 — persulphate	$(NH_4)_2S_2O_8$	228.20	
4 — phosphomolybdate	$(NH_4)_3PO_4.10MoO_3+3H_2O$	1643.2	
5 — platinibromide	$(NH_4)_2PtBr_6$	710.8	4.2
6 — platinichloride	$(NH_4)_2PtCl_6$	444.0	3.065
7 — sequicarbonate	$2NH_4HCO_3(NH_4)_2CO_3+H_2O$	272.2	
8 — stannichloride	$(NH_4)_2SnCl_6$	367.5	
9 — sulphate	$(NH_4)_2SO_4$	132.14	1.77/20°
10 — sulphide	$(NH_4)_2S$	68.14	
11 — sulphite	$(NH_4)_2SO_3$	116.14	
12 — thiocyanate	NH_4CNS	76.12	1.3057/13°
13 Antimonic acid	$HSbO_3$	169.2	6.6
14 Antimonious acid	$HSbO_2$	153.2	
15 Antimony	Sb	120.2	6.62
16 — chloride (basic)	$2SbOCl;Sb_2O_3$	631.7	
17 — hydride (stibine)	SbH_3	123.2	D:4.36/15°
18 Antimonyl sulphate	$(SbO)_2SO_4$	368.5	4.89
19 — (basic)	$(SbO)_2Sb_2(OH)_4SO_4$	676.9	
20 Antimony oxychloride	$SbOCl_3$	242.6	
21 — oxychloride	$SbOCl$	171.7	
22 — pentachloride	$SbCl_5$	297.5	2.316
23 — pentafluoride	SbF_5	215.2	2.993/23°
24 — pentasulphide	Sb_2S_5	400.8	4.12/0°
25 — pentiodide	SbI_5	754.8	
26 — pentoxide	Sb_2O_5	320.4	3.8
27 — sulphate	$Sb_2(SO_4)_3$	528.6	
28 — tetroxide	Sb_2O_4	304.4	4.07
29 — tribromide	$SbBr_3$	360.0	4.148/23°;
30 — trichloride	$SbCl_3$	226.6	D:7.96,3.06/26° 2.67/72°

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
IV.	20		s.s. alc.	d.		1
Needles	8.0			slowly heated— d.	rapidly heated— expl. d.	2
V.	58.2 (0°)	d.				3
Y.	0.03		i. alc.			4
I. Oct.	0.5			d.		5
Y.	0.67	12.5		d.		6
IV.	20	d.		d.		7
I. P.	33.3	s.				8
IV. C.	74.2	103.3		d. 140		9
	v.s.			d.		10
V.	100 (12°)		i. alc.	d.		11
V. C.	162.2 (20°)		s. alc.	149.5	d. 170	12
W.	s.s.	s.s.	s. ac., s. KOH			13
	i.	i.	i. alc.	d.		14
IIIa. W.			s.h. HCl., s. H_2SO_4	630.0	R.H.	15
III. W.	i.			d.		16
W.	20 vol.		1500 vol. in alc.	− 91.5	− 18	17
W.	d.					18
W.	i.	d.				19
Y.	d.		s. alc.			20
I., IIIa.	i.	d	i. alc., s. HCl, CS_2	d.	d.	21
V. W.	d.			− 6	102/68 mm.	22
	s.		s. KF soln.		155	23
Or.	i.	i.	s. NH_4HS	d.		24
Br.					78—79	25
Y.W.	v.s.s.	i.	s. HCl, s.s. KOH	d. 300		26
W. needle	d.					27
W.	i.	i.	s. alk., s.s. ac.	infusible		28
IV. C.	d			93	280	29
IV. C.	s.,quickly d.		s. conc. HCl, s. alc.	73.2	223	30

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Antimony trifluoride	SbF_3	177.2	
2 —, sodium sulphate	SbF_3, Na_2SO_4	319.3	
3 — tri-iodide	SbI_3	501.0	(1) 4.85/26°
			(2) D :17.6
			(3) 4.77/22°
4 — trioxide	Sb_2O_3	288.4	5.556 nat. ;
			5.2 (1)
5 — trisulphide	Sb_2S_3	336.6	(1) 4.65
			(2) 4.15
6 Argon	A	39.88	
7 Arsenic, cryst.	As	74.96	5.73/14°
8 — amorph.	As	74.96	4.71
9 — acid, ortho-	$2AsO(OH)_3 + H_2O$	301.98	2—2.5 gas.
10 — — pyro-	$As_2O_3(OH)_4$	265.95	
11 — — meta-	$AsO_2.OH$	123.97	
12 — di-iodide	As_2I_4	657.60	
13 — disulphide	As_2S_2	214.04	3.54
14 — hydride (arsine)	AsH_3	77.98	
15 — — (solid)	As_2H_2	151.94	
16 — oxychloride	$AsOCl$	126.42	
17 — pentasulphide	As_2S_5	310.20	
18 — pentoxide	As_2O_5	229.92	3.754
19 — phosphide	AsP	106.00	
20 — selenide	As_2Se_3	387.51	4.75
21 — tribromide	$AsBr_3$	314.72	3.7/15°
22 — trichloride	$AsCl_3$	181.34	2.205/0°
23 — trifluoride	AsF_3	131.96	2.666
24 — tri-iodide	AsI_3	455.72	4.4/13°
25 — trisulphide	As_2S_3	246.10	3.46 ;
			amorph. 2.76

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
	s., d.			292		1
	s.	s.				2
(1) III. R	d.		s. alc., CS$_2$, HCl	167 subl. 114	401	3
(2) IV. Y.						
(3) V. R.						
IV., l.	i.		s. conc. HCl, tartaric acid	R.H.	subl. 1550	4
(1) III. Bl	i.	i.	s. am. sulph.	555	diss.	5
(2) Am. Br						
	4 (20°)			−189.6	−186.1	6
Gr.Bl.	i.	i.	s. ac.	subl. 450		7
Y. vapour	i.	i.	s. CS$_2$	subl.		8
W. cryst.	16.7	50		aq 180		9
	becomes ortho			d. 206 to meta		10
	becomes ortho			d. R.H.		11
R. prism		d.	s. alc., ether, CS$_2$, CHCl$_3$			12
V. R.	i.	i.	s. KHS, NaHCO$_3$	fusible		13
	5 vols.	s.s.	s.s. alc.	−113	−54.8	14
Br.	i.			d. 200		15
Br.	d.			fusible	d.	16
Y.	i.	i.	s. alc.	fusible	subl.	17
Am. W.	245	v.s.	v.s.	R.H.	d.	18
Br.R. pdr.	d.		i. ac., alc.	d.	d.	19
C. cryst.	i.	d.	s. alk.	360		20
	d.		s. HCl	31	221/745	21
	s., rapid d		s. HCl, alc.	liq. −18	130.2	22
	d		s. NH$_3$ soln.	−8.5	60.4	23
IIIa. Y.	s.	l.	s. alc., ether	subl. 146	394—414	24
Y	i.	i	s. alc.		>700	25

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Arsenious oxide	As_2O_3	197.92	cryst. 3.699 ; amorph. 3.738
2 Auric chloride	$AuCl_3$	303.6	3.9
3 — cyanide	$Au(CN)_3 + 3\ H_2O$	329.3	
4 — hydroxide	$Au(OH)_3$	248.2	
5 — oxide	Au_2O_3	442.4	
6 Auro-auric sulphide	Au_2S_2	458.5	
7 Aurous bromide	$AuBr.$	277.1	
8 — chloride	$AuCl$	232.7	
9 — cyanide	$AuCN$	223.2	
10 — hydroxide	$AuOH$	214.2	
11 — iodide	AuI	324.1	
12 — oxide	Au_2O	410.4	3.6
13 — — sulphide	Au_2S	426.5	
14 Azoimide	N_3H	43.04	
15 Barium	Ba	137.37	3.78
16 — bromate	$Ba(BrO_3)_2(+H_2O)$	393.21	4.04/17°
17 — bromide	$BaBr_2 + 2\ H_2O$	333.24	3.85/24°
18 — carbide	BaC_2	161.38	3.75
19 — carbonate	$BaCO_3$	197.37	4.275
20 — chlorate	$Ba(ClO_3)_2 + H_2O$	322.31	3.179
21 — chloride	$BaCl_2 + 2\ H_2O$	244.32	3.1/24°
22 — chromate	$BaCrO_4$	253.4	3.9
23 — dithionate	$BaS_2O_6 + 2\ H_2O$	333.52	4.536/13.5°
24 — ferrocyanide	$Ba_2Fe(CN)_6 + 6\ H_2O$	594.77	
25 — fluoride	BaF_2	175.4	ppd. 4.828
26 — hydride	BaH_2	139.39	4.21/0°
27 — hydrogen phosphate	$BaHPO_4$	233.42	4.165
28 — — sulphide	$Ba(HS)_2(+4\ H_2O)$	203.51	

Crystalline form and colour	*—Solubility*in— 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Am., I.; W	1.7	9.5	s. HCl.	subl. 218		1
Y.R.	68	s.	s. alc.	subl.	d. 180	2
C. plates	v.s.	d.		50	d.	3
Y.Br.	i.	i.	s. HNO_3	d.		4
Bl.	i.	i.	s. HCl	d. > 100		5
Bl.	i.	i.	s. am. sulph.	d.		6
G.	i.	i.	d. ac.	d. > 150		7
Y.	d.			d.		8
Y.	i.	i.	i. alc., s. KCN	d.		9
R.B.	s. —blue		—	d. 250		10
Y.	i.	d.		d. < 120		11
Br.Bl.	i.	i.	s. HCl	d. 250		12
Dark pdr.	an. i.		s. KCN			13
C.	m.	m.	s. alc., alk.	liq.	37	14
W.	d.			850	1000	15
V. C. cryst	0.7	5.4		d. 260		16
IV.	103	204	s. alc.	880 2 aq, 120		17
Bl. cryst.	gives acetylene					18
IV. W.	i.	i.	i. alc	795	d. 1450	19
V.	33.4	126	s.s. alc.	an. 414	(+aq 120)	20
IV.	34.5	58.8	i. alc., s.s. HCl, HNO_3	2aq, 113 960		21
Y.	i.	i.	s. ac.			22
IV.	24	90.9		d.		23
Prism.	0.17	0.9				24
Am., W.	v.s.s.		s. NH_4Cl; s. HF	1280		25
Gr.	d.			abt. 1200	1400	26
IV.	i.	i.	s. ac., s. NH_4Cl			27
IV.	s.	s.	i. alc.	d. 50		28

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Barium hydroxide	$Ba(OH)_2+8 H_2O$	315.52	an. 4.495
2	— hypophosphite	$Ba(H_2PO_2)_2+H_2O$	285.50	2.89/17°
3	— iodate	$Ba(IO_3)_2$	487.21	4.998
4	— iodide	$BaI_2+2 H_2O$	427.24	an. 4.917
5	— manganate	$BaMnO_4$	256.3	4.85
6	— monoxide	BaO	153.37	4.7—5.5
7	— nitrate	$Ba(NO_3)_2$	261.39	3.24/23°
8	— nitrite	$Ba(NO_2)_2$	229.39	
9	— perchlorate	$Ba(ClO_4)_2$	336.29	
10	— peroxide	BaO_2	169.37	4.958
11	— — (hydrate)	$BaO_2+8 H_2O$	313.50	
12	— persulphate	$Ba(SO_4)_2+4 H_2O$	401.55	
13	— phosphate, ortho	$Ba_3(PO_4)_2$	602.19	4.1
14	— —, pyro	$Ba_2P_2O_7$	448.82	3.9/20°
15	— platinichloride	$BaPtCl_6+4 H_2O$	617.4	2.86/8°
16	— platinocyanide	$BaPt(CN)_6+4 H_2O$	560.7	3.05
17	— silicofluoride	$BaSiF_6$	279.5	4.29/21°
18	— sulphate	$BaSO_4$	233.43	4.486—4.53
19	— sulphide	BaS	169.43	4.30
20	— sulphite	$BaSO_3$	217.43	
21	— tetrahydrogen phosphate	$BaH_4(PO_4)_2$	331.48	2.9/4°
22	— tetrasulphide	BaS_4	265.61	2.98/20°
23	Bismuth	Bi	209.0	9.76
24	— carbonate, basic	$2(BiO)_2CO_3+H_2O$	1036.0	
25	— hydroxide	$Bi(OH)_3$	260.0	
26	— iodate	$Bi(IO_3)_3$	733.8	
27	— nitrate	$Bi(NO_3)_3+5 H_2O$	485.1	2.8
28	— — (basic)	$Bi(OH)_2NO_3$	305.0	
29	— oxychloride	$BiOCl$	260.5	7.717/15°
30	— pentoxide	Bi_2O_5	498.0	
31	— phosphate	$BiPO_4$	304.0	6.323/15°
32	— sulphate	$Bi_2(SO_4)_3$	706.2	

crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
II. W.	3.3	101.5 (80°)	v.s.s. alc.	loses 7 aq. in air 1aq.atR.H		1
V.	30	33	i. alc.	d.		2
V.	.022	0.197	s. HNO$_3$, HCl	d.		3
IV.	200	300	v.s.	740		4
III. G.	i.		s. ac.			5
Am., I. Gr.	combines with H$_2$O		s. ac.	W.H.		6
I.	8.1	32.2	i. alc.	575		7
III. Pyr.	63/20°	v.s.	v.s. HCl, s. alc.	d. 115		8
III.	s.		s. alc.	505		9
Gr.	i.	d.	s. HCl	R.H.		10
III.	v.s.s.	d.		6 aq. : 130		11
V.	v.s.	d.				12
	i.	i.	s. ac.			13
IV. W.	s.s.	s.s.	s. ac.			14
V. P.			d. alc.			15
IV. G.	0.33	s.	s. alc.			16
	0.26	s.s.	i. alc., s.s. ac.			17
IV.	i.	i.	s.s. H$_2$SO$_4$	1500		18
IV.	d.		i. alc.	d.		19
I., prism.	i.		s. ac.			20
VI.	d.		s. ac.			21
						22
IV. P.	50		i. alk.	268	1090—1450	23
IIIa. W. pdr.	i. i.	i.	s. HNO$_3$	aq 100	becomes Bi$_2$O$_3$	24
W.	i.		s. ac.	aq 100		25
	i.		s.s. HNO$_3$			26
VI.	d.		s. HNO$_3$	74	5 aq 80	27
VI. W.	i.		s. min. ac.	d.		28
W., cryst.	i.		s. HCl	R.H.		29
R. Br.	i.	i.	s. HCl	d. 225		30
Micro cryst	i.	i.		d.		31
W	d.			d.		32

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Bismuth tribromide	$BiBr_3$	448.8	5.604
2	— trichloride	$BiCl_3$	315.4	4.6/11°
3	— tri-iodide	BiI_3	589.8	5.65/20°
4	— trioxide	Bi_2O_3	466.0	8.868
5	— trisulphide	Bi_2S_3	514.2	6.5 ppd.
6	Borax	$Na_2B_4O_7+10\,H_2O$	386.2	1.69
7	Boric acid	H_3BO_3	63.0	1.4347/15°
8	Borofluoric acid	HBF_4	89.0	
9	Boron	B	10.9	2.68 ; am. 2.45
10	— nitride	BN	24.9	
11	— tribromide	BBr_3	250.7	2.69
12	— trichloride	BCl_3	117.3	1.35/0°
13	— trifluoride	BF_3	67.9	
14	— tri-iodide	BI_3	391.7	3.3/50°
15	— trioxide	B_2O_3	69.9	1.83/4°
16	— trisulphide	B_2S_3	118.0	1.55
17	Bromic acid	$HBrO_3$	128.93	
18	Bromine	Br	79.92	3.1872
19	— monochloride	$BrCl+10\,H_2O$	295.54	
20	— mono-iodide	BrI	206.84	4.4157/0°
21	— sulphide	Br_2S_2	223.96	2.629
22	Cadmium	Cd	112.40	8.64
23	— bromide	$CdBr_2$	272.24	4.794/20°
24	— carbonate	$CdCO_3$	172.40	4.49
25	— chlorate	$Cd(ClO_3)_2+2\,H_2O$	315.35	2.284/18°
26	— chloride	$CdCl_2+2\,H_2O$	219.35	3.6/15°
27	— — anhydr.	$CdCl_2$	183.32	3.655/17°
28	— fluoride	CdF_2	150.40	5.99/22°
29	— hydroxide	$Cd(OH)_2$	146.42	4.79
30	— iodate	$Cd(IO_3)_2+H_2O$	480.25	
31	— iodide	CdI_2	366.24	4.576
32	— nitrate	$Cd(NO_3)_2+4\,H_2O$	312.48	2.45

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Y., prism.	deliq., d.		s. HCl	210—215	453	1
W., cryst.	deliq., d.		s. HCl	227	429	2
Bl., cryst.	s.	d.	s. HI	subl.	<439	3
Y.W.	s.		s. alc.	ppd. 820		4
IV.	i.		s. HNO_3	d.		5
V.,+5aq.I.	6.2	201.4	i. alc.	R.H.		6
VI.	4	34	1 : 6 alc.	185,aq.100,		7
	s.	s.		liq.	d. 130	8
V., Y.;	i.	i.	i. alc.	2200—2500		9
Am., W.	i.	i.	d. HF			10
	d.			liq.	90.5	11
O.	d.			liq.	18.2	12
	1000 vol. in 1	d.	d. in alc.	-127	-101	13
C. cryst.	d.		s. CS_2 and O_6H_6	43	210	14
C.	d.		s. alc.	<1500		15
W.	d.		d., s. PCl_3	310		16
C.	s.	s.		d. 100		17
Br.	3.5	—	s. alc.	-7.3	63	18
Y.	v.s.			an. 7		19
	d.		s. CS_2 and $CHCl_3$	36		20
R.	d.			liq.	190—200	21
III.	i.	i.	s. HNO_3, HCl	320.9	778	22
W.	deliq.	49	s. HCl, s. alc.	580	863	23
W.	i.	i.	s. ac.			24
Prism.	deliq.	v.s.	s. alc.	d. 80		25
Cryst.	140	150	s. alc.	590	900	26
	140.8	150	s. alc.	560	964	27
	s.s.	s.s.	s. HF., i. alc.	520		28
W.	i.	i.	s. ac.	aq 300		29
V., small cryst.	s.s.	s.s.	s. HNO_3	d.		30
Cryst.	89	132	s. alc., ether	350	716	31
	127	v.s.	s. alc.	59.5	132	32

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Cadmium oxide	CdO	128 40	6.95
2	—sulphate	(a) 3 CdSO$_4$+8 H$_2$O	769.51	
		(b) CdSO$_4$+4 H$_2$O	284.52	3.05
3	— sulphide	CdS	144.50	4.58 ppd.
4	Cæsium carbonate	Cs$_2$CO$_3$	325.62	
5	— chloride	CsCl	168.27	3.972/20°
6	— hydroxide	CsOH	149.82	4.018/4°
7	— nitrate	CsNO$_3$	194.82	3.687/28°
8	— platinichloride	Cs$_2$PtCl$_6$	673.6	
9	— silicofluoride	Cs$_2$SiF$_6$	407.7	3.375/17°
10	— sulphate	Cs$_2$SO$_4$	361.68	4.250/16°
11	Calcium	Ca	40.07	1.554/18°
12	— arsenate	Ca$_3$(AsO$_4$)$_2$	398.13	
13	— bromide	CaBr$_2$(+6 H$_2$O)	199.91	3.32/20°
14	— carbide	CaC$_2$	64.08	2.22/18°
15	— carbonate	CaCO$_3$	100.08	2.72—2.9
16	— chlorate	Ca(ClO$_3$)$_2$(+2 H$_2$O)	206.99	
17	— chloride	CaCl$_2$+6 H$_2$O	219.09	1.6775/17°
18	—— anhydr.	CaCl$_2$	110.99	2.26/20°
19	— chromate	CaCrO$_4$ + 2 H$_2$O	192.1	
20	— cyanide	Ca(CN)$_2$	92.10	
21	— cyanamide	CaCN$_2$	80.09	
22	— ferrocyanide	Ca$_2$Fe(CN)$_6$+12 H$_2$O	508.31	
23	— fluoride	CaF$_2$	78.07	3.18
24	— hydrogen phosphate	CaHPO$_4$+2 H$_2$O	172.15	2.3
25	— hydrosulphide	Ca(HS)$_2$(+6 H$_2$O)	106.21	
26	— hydroxide	Ca(OH)$_2$	74.09	2.078 am.
27	— hypochlorite	Ca(OCl)$_2$+4 H$_2$O	215.05	
28	— hypophosphite	Ca(H$_2$PO$_2$)$_2$	170.18	
29	— iodate	Ca(IO$_3$)$_2$(+6 H$_2$O)	389.91	
30	— iodide	CaI$_2$(+6 H$_2$O)	293.91	4.9/20° an.

Crystalline form and colour	Solubility* in 100 parts water at 15°C (60°F)	Solubility* in 100 parts water at 100°C (212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
I., Br., R.	i.	i.				1
V.	59	v.s.		an.		2
	95	v.s.	i. alc.	1000		
III. Y.	i.	i.	s. conc. ac.	W.H.		3
	deliq.	v.s.	s. alc. 11.1/19°	<R.H.	d. 610	4
I. O.	174	v.s.	s. alc.	631	subl.	5
	deliq.	v.s.	s. alc.			6
II.	10.58/3.2°	v.s.	s.s. alc.	414	d.	7
I. Y.		v.s.s.				8
I.	6	s.	i. alc.			9
O.	158.7/–2°	v.s.	i. alc.			10
IIIa. Y.	d.		d.	805		11
	i.	i.				12
W. needles	140	310	v.s. alc.	760	800	13
Gr. Y. cryst.	gives C_2H_2	not d. conc. H_2SO_4				14
IIIa, IV.	0.0018	0.088	CO_2 with acids	d. 825		15
V.	deliq.	v.s.	v.s.alc., s.acet.	d.		16
III.	400	650	alc. 13	29	4 aq 30 in vacuo, 6 aq 200	17
Am. W.	66	155		780		18
Y. cryst.	0.4	s.		2 aq R.H.		19
I.	s.	s.				20
		s. d.		d.		21
Y. prism.	(+12 aq) <150	150 (90°)		d.		22
I.	0.05	v.s.s.		1330		23
V. W.	s.s.	d.	s. amm.cit ate	an. 100		24
Cryst.	v.s.		s. alc.	d.		25
W. needles	0.137	0.075	i. alc.			26
	deliq. & s.			d.		27
V.	17	slightly >17	i. alc.	d. R.H.		28
IV.	0.4	1.33	s. HNO_3	d.		29
W. plates	201	435/92°	s. acetone	740		30

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Calcium nitrate	$Ca(NO_3)_2 + 4H_2O$	236.15	1.878/18°
2 — nitride	Ca_3N_2	148.23	2.63/17°
3 — nitrite	$Ca(NO_2)_2(+H_2O)$	132.09	
4 — oxide	CaO	56.07	3.08
5 — peroxide	$CaO_2 + 8H_2O$	216.20	
6 — phosphate, ortho-	$Ca_3(PO_4)_2$	310.29	3.18
7 — — meta-	$Ca(PO_3)_2$	198.15	
8 — — pyro-	$Ca_2P_2O_7(+4H_2O)$	254.22	
9 — phosphide	Ca_3P_2	182.29	2.51/15°
10 — plumbate	Ca_2PbO_4	351.34	
11 — plumbite	$CaPbO_2$	279.27	
12 — potassium sulphate	$CaSO_4K_2SO_4 + H_2O$	328.41	2.6/17°
13 — sodium sulphate	$CaSO_4 2Na_2SO_4 + 2H_2O$	456.28	
14 — sulphate (gypsum)	$CaSO_4 + 2H_2O$	172.16	2.306/15°
15 — sulphide	CaS	72.13	2.8
16 — sulphite	$CaSO_3 + 2H_2O$	156.17	
17 — tetrahydrogen orthophosphate	$CaH_4(PO_4)_2 + H_2O$	252.20	2/4°
18 — thiosulphate	$CaS_2O_3 + 6H_2O$	260.29	1.87
19 Carbon (diamond)	C	12.00	3.48—3.53
20 — (graphite)	C	12.00	2.14—2.27
21 — dioxide	CO_2	44.00	liq. 0.83; solid. 1.2
22 — disulphide	CS_2	76.12	D.2.68; 1.292
23 — monoxide	CO	28.00	liq. 0.7929
24 — oxysulphide	COS	60.06	
25 — tetrachloride	CCl_4	153.84	1.582/21°
26 Carbonyl chloride (phosgene)	$COCl_2$	98.92	1.432/0° 1.392/18.6°
27 Ceric sulphate	$Ce(SO_4)_2$	332.37	
28 Cerium	Ce	140.25	6.6—7.0
29 — dioxide	CeO_2	172.25	6.74
30 — sesquioxide	Ce_2O_3	328.50	6.9—7.0

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	Solubility in 100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
V.	54.8	v.s.	s. alc.	44, an. 561	d. 132	1
Br.	d.			900		2
III., prism	v.s.	v.s.	s.s. alc.	aq 100		3
O., I.	d.		s. alc.			4
II.	s.s.		i. alc.	8 aq 130	d.	5
W.	i.	i.	s. ac.	fusible		6
W.	i.	i.	i ac.			7
W.	i.		s. ac.			8
Cryst.	yields pure PH_3			burns in O at 300		9
Br., cryst.	i.	d.	d. ac.	d.		10
Cryst.		s.s.		d.		11
V.	s.s.	d.	i. alc.			12
V.		d.		2 aq 80		13
V. W.	0.24 (0°)	0.22	i. alc.	2 aq 130		14
I. W.	d.				d.	15
W. needles	0.125		s. SO_2 soln	2 aq 100		16
IV.	0.128	0.079	s. acids	aq 100	d. 200	17
VI.	100 (3°)	d.		d.		18
I., C.	i.	i.	i			19
III., Gr.	i.	i.	— i			20
	1.797 in 1 vol. (0°)		alc. 1 :3.2 vol. (15°)	− 65	− 78.2	21
	2 :1000/0° 30 vol.	1.4 :10000/ 50°	m. alc.	− 116	46	22
			sol. in am. or acid Cu_2Cl_2	− 207/100 mm.	− 190	23
gas.	1 :1 vol.			d.	0° at 12 atm.	24
	i.			− 23.8	76.7	25
	d.		d. alc.	gas	8	26
Y. cryst. pdr.	forms basic salt					27
Gr. met.	d.		s. HCl, HNO_3	623		28
W pdr.	i.	i.	s. H_2SO_4			29
G pdr.			s. H_2SO_4, i. HCl			30

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Cerous carbonate	$Ce_2(CO_3)_3 + 5 H_2O$	550.59	
2 — chloride	$CeCl_3$	246.63	3.88/15.5°
3 — phosphate	$CePO_4$	235.29	5.92/14°
4 — sulphate	$Ce_2(SO_4)_3$	568.68	3.91
5 Chlorauric acid	$HAuCl_4 + 4 H_2O$	412.1	
6 Chloric acid	$HClO_3 (+7 H_2O)$	84.47	liq. : 1.33/14°; D : 2.4502/200°
7 Chlorine	Cl	35.46	
8 — dioxide	ClO_2	67.46	1.5 ; D : 2 39
9 — heptoxide	Cl_2O_7	182.92	
10 — hydrate	$Cl_2 + 8 H_2O$	215.05	1.2
11 — monoxide	Cl_2O	86.92	liq. 3.87
12 Chlorplatinic acid	H_2PtCl_6	410.0	2.431
13 Chlorsulphonic acid	$ClSO_2OH$	116.53	1.72/18°
14 Chromic acid	H_2CrO_4	118.0	
15 — bromide	Cr_2Br_6	583.5	
16 — chloride	Cr_2Cl_6	317.8	D : 5.51/1277°; 2.76/15°
17 — fluoride	Cr_2F_6	218.0	3.78
18 — hydroxide	$Cr_2(OH)_6 + 4 H_2O$	278.1	
19 — nitrate	$Cr(NO_3)_3 + 9 H_2O$	400.17	
20 — sulphate	$Cr_2(SO_4)_3 + 18 H_2O$	716.5	1.867/15°
21 — sulphide	Cr_2S_3	200.2	3.77
22 Chromium	Cr	52.0	6.92/20°
23 — sesquioxide	Cr_2O_3	152.0	5.21 cryst.
24 — trioxide	CrO_3	100.0	2.74 cryst.
25 Chromous chloride	$CrCl_2$	122.9	2.75/14°
26 Chromyl chloride	CrO_2Cl_2	154.9	1.96
27 Cobalt	Co	58.97	8.951
28 Cobaltic chloride	Co_2Cl_6	330.70	2.94
29 — —, luteo	$Co_2(NH_3)_{12}Cl_6$	535.08	1.7/20°
30 — —, prasco	$Co_2(NH_3)_8Cl_6 + 2 H_2O$	503.00	
31 — —, purpureo	$Co_2(NH_3)_{10}Cl_6$	501.00	1 802/23°
32 — —, roseo	$Co_2(NH_3)_{10}Cl_6 + 2 H_2O$	537.0	
33 — —, xantho	$Co_2(NH_3)_{10}(NO_2)_2Cl_4$	522.10	
34 Cobalticyanic acid	$(H_3Co(CN)_6)_2 + H_2O$	454.18	

Crystalline form and colour	Solubility* in			M.P. °C.	B.P °C.	
	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies			
Plates	i.		s. $(NH_4)_2CO_3$			1
C.	s.		s. alc.	fusible	d.	2
V. R.	i.	i.	i. ac.			3
G. pdr.	40/0°	0.775				4
Y. needles	s.	v.s.	s. alc.	d.		5
	s.			d.	d.	6
G.	1 :2.6 vol.	1 :1.4, 40°		− 102	− 33.5	7
R.	20 vol. :1		alk. d.	− 76	10/731 mm.	8
C.	d.		s. C_6H_6		82	9
I. Y.	s.		s. HCl	d. 9.6		10
Y. R.	s.			expl.	19	11
R. cryst.	deliq.	v.s.				12
C.	d.		d.	liq.	158	13
R. cryst.	s.	v.s.		givesCrO_3		14
dark.	i.	s.	alk. d.	subl.		15
P.	i.	i.	i. alc.		1300	16
G.	i.			>1000	subl.	17
B.	i.	i.	s. ac., alk.	3 aq in vac		18
			s. $NaHSO_3$	4 aq 100		
Viol. prism	s.	v.s.	s. alk.	36.5		19
I., Viol.	120	s. green 90°	s. alc.	4 aq 100	an. 400	20
R.			s. HNO_3			21
IIIa, G.	i.	i.	s.HCl, i.HNO_3	1505		22
III., G.	i.	i.	i. alc.	W. H.		23
IV., R.	v.s.	v.s.	alc. d.	190	d.	24
W.	s.	s.		fusible		25
R.	d.		alc. d.	liq.	116	26
Gr. met.	i.	i.	s. ac.	1490		27
	s.	s.	s. alc.	d.		28
V. R.Y.	1 :16.8	v.s.	s. conc. HCl	d.		29
G. cryst.	v.s.			d.		30
	1 :255	s.	s. conc. H_2SO_4	d.		31
R. cryst.	1 :4.8	d.	i. alc.	d. 100		32
Y. cryst.	s.s.	s. d.		d.		33
C. needles	deliq.		s. alc.	d. <100		34

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Cobaltic hydroxide	$Co_2(OH)_6$	219.99	
2 — oxide	Co_2O_3	165.94	5.1
3 Cobalto-cobaltic oxide	Co_3O_4	240.91	5.8—6.3
4 Cobalt arsenate	$Co_3(AsO_4)_2 + 8\,H_2O$	598.96	2.948
5 — bromide	$CoBr_2 + 6\,H_2O$	326.91	
6 — carbonate	$CoCO_3$	118.97	
7 — chlorate	$Co(ClO_3)_2 + 6\,H_2O$	333.99	
8 — chloride	$CoCl_2 + 6\,H_2O$	237.99	1.84
9 ——, anhydr.	$CoCl_2$	129.89	2.94
10 — cyanide	$Co(CN)_2 + 3\,H_2O$	165.05	
11 — hydroxide	$Co(OH)_2$	92.99	3.507/15°
12 — nitrate	$Co(NO_3)_2 + 6\,H_2O$	291.09	1.83
13 — phosphate	$Co_3(PO_4)_2 + 8\,H_2O$	511.12	
14 — oxide	CoO	74.97	5.68
15 — silicate	Co_2SiO_4	210.0	4.63
16 — sulphate	$CoSO_4 + 7\,H_2O$	281.14	1.98/15°
17 — sulphide	CoS	91.03	
18 — tetracarbonyl	$Co_2(CO)_8$	341.98	
19 — tricarbonyl	$Co(CO)_3$	142.99	
20 Columbium	Cb	93.1	8.4
21 — dioxide	Cb_2O_2	218.2	6.3
22 — hydride	CbH	94.1	6.6
23 — oxychloride	$CbOCl_3$	215.5	D:7.88/400°
24 — pentachloride	$CbCl_5$	270.4	D:9.6/360°; 4.4—4.5
25 — pentoxide	Cb_2O_5	266.2	4.53—4.57
26 Copper	Cu	63.57	8.94/20°
27 — carbonate, basic (malachite)	$CuCO_3 + Cu(OH)_2$	221.16	3.65—4.05
28 —— (azurite)	$2CuCO_3 + Cu(OH)_2$	344.73	3.88
29 — dioxide	$CuO_2 + H_2O$	113.59	
30 Cuprammonium sulphate	$CuSO_4 + 4NH_3 + H_2O$	245.80	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Bl.	i.	i.	i. alc., d. HCl		6 aq 100	1
Br.	i.	i.	i. alc., s. ac.	d. R.H.		2
I., Bl.	i.	i.	s. conc. H_2SO_4			3
V., Viol.	i.	i.	s. HCl	d.		4
R. prism.	s.	v.s.	s. alc., ether	4 aq 100, 2 aq 130	an. 130	5
IIIa, R.	i.	i.	alc.	d.		6
I.	deliq.		s. alc.	50	d. 100	7
V., R.		s.	s. alc.	86.75	6 aq 110	8
B.	50	108	s. alc.	subl. in Cl		9
Am. R.	i.		s. KCN	3 aq 250		10
P. cryst.	i.	i.	s. NH_4OH			11
P. cryst.	deliq.	v.s.	alc. 200	d. R.H.		12
	i.	i.	i. alc.	d.		13
Br.	i.	i.	i. alc.	d. 100		14
Viol.	i.		d. HCl			15
IV., R.	32.0	82.6	i. alc.			16
Gr., Pr.	i.	i.	s. acids			17
Or. cryst.	i.		s. alc. CS_2	51	d. 60	18
Bl. cryst.	s.s.		d. with Br			19
Gr.			s. conc. H_2SO_4	1950		20
I. Bl.	i.	i.	s. HCl			21
Gr., pdr.			s. HF, conc. H_2SO_4	ignites		22
W.	d.		s. KOH, alc.		subl. 400	23
Y. needles	d.		s. HCl, CCl_4	194	240.5	24
Am. W., cryst. G.	i.	i.	s. H_2SO_4	infusible		25
I., R.	i.	i.	s. ac.	1083.0		26
V. G.	i.	i.	s. NH_4OH	d.		27
V. B.	i.	i.		d.		28
Y.Br.	i.		i. alc.	aq d. 6	an. d. 180	29
IV. B.	60	d.	i. alc.	d. 150		30

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Cupric arsenite	$CuHAsO_3$	187.54	
2 — bromide	$CuBr_2$	223.41	
3 — chlorate	$Cu(ClO_3)_2 + 6 H_2O$	338.59	
4 — chloride	$CuCl_2 + 2 H_2O$	170.52	2.47
5 — hydroxide	$Cu(OH)_2$	97.59	3.368
6 — nitrate	$Cu(NO_3)_2 + 6 H_2O$	295.69	2.047
7 — oxide	CuO	79.57	6.304
8 — oxychloride	Cu_2OCl_2	214.06	
9 — phosphate	$Cu_3(PO_4)_2 + 3 H_2O$	434.84	
10 — sulphate	$CuSO_4 + 5 H_2O$	249.71	2.274/15°
11 — sulphide	CuS	95.63	4.59
12 Cuprous acetylide	$Cu_2C_2.H_2O$	169.17	
13 — bromide	Cu_2Br_2	286.98	4.72
14 — chloride	Cu_2Cl_2	198.06	D. 6.6/1690°;
15 — cyanide	$Cu_2(CN)_2$	179.17	3.7
16 — hydride	Cu_2H_2	129.16	
17 — hydroxide	$4Cu_2O + H_2O$	590.58	
18 — iodide	Cu_2I_2	380.98	5.67
19 — oxide	Cu_2O	143.14	5.8—6.1
20 — sulphate	Cu_2SO_4	223.20	
21 — sulphide	Cu_2S	159.20	5.58 artif.
22 — sulphite	$Cu_2SO_3 + H_2O$	225.22	4.46
23 Disulphuryl chloride	$S_2O_5Cl_2$	215.04	1.819/20° D. 7.4
24 Ferric arsenate	$FeAsO_4 + 2 H_2O$	230.83	3.18
25 — arsenite	$4 Fe_2O_3 + As_2O_3 + 5 H_2O$	926.72	
26 — bromide	Fe_2Br_6	591.20	
27 — chloride	Fe_2Cl_6	324.44	D:11.2/320°; 2.8/11°
28 — ferrocyanide (Insoluble Prussian blue or Turnbull's blue)	$Fe_4(FeC_6N_6)_3$	859.15	
29 — hydroxide	$Fe_2(OH)_6$	213.73	3.4—3.9

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C	B.P. °C.	
G.	i.		s. alc.	d.		1
B.	deliq.			d.		2
G.	v.s.	v.s.	s. alc.	65	d.	3
IV., B.	121	v.s.	s. alc.	100	d. R.H.	4
B.	i.		s. NH_4OH	d.		5
B. cryst.	v.s.	v.s.	v.s.	38	d.	6
I. & V., Bl.	i.	i.	i. alc.			7
Y.	d.			d.		8
IV., B.	s.s.	d.	s. H_3PO_4			9
VI., B.	40	203	i. alc.	4 aq 100, 5 aq 240	d. R.H.	10
III., Bl.	i.	i.	i. alc.	d.		11
Am. R.			with ac. : O_2H_2	expl.		12
Br. B.	i.		s. NH_4OH	504	861—894	13
I. W.	v.s.s		s. HCl, NH_4OH	410	abt. 1000	14
W.			s. HCl, H_2SO_4	R. H.	d.	15
	d.		d. HCl	d. 60		16
Y.	i.		s. NH_4OH	d. 360		17
W. cryst.	i.	i.	s. NH_4OH	628		18
I., R.	i.	i.	s. NH_4OH	fusible		19
Gr. pdr.	d.			oxidises at 200		20
IV., Bl.	i.	i.	i. alc.	1091		21
III., R.	s.s.			d.		22
	d.			− 39	146	23
IV., W.	i.	i.		d.		24
Br.	v.s.s		s. HCl	d.		25
R. cryst.	deliq.	s.	s. alc.	d.	subl. & d.	26
III.,Br.,Bl	158	537	s. alc.	301	280—285	27
Am. B.	i.	i.	s. oxalic acid	d.		28
R., Br.	i.	i.	i. alc., s ac.	d.		29

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Ferric nitrate	$Fe_2(NO_3)_6 + 18 H_2O$	808.10	1.6835
2	— oxide	Fe_2O_3	159.68	5.2—5.3
3	— phosphate	$Fe(PO_4) + 2 H_2O$	186.91	2.87
4	— potassium ferro-cyanide (Soluble Prussian blues)	$KFe(FeC_6N_6)$	306.87	
5	— sulphate	$Fe_2(SO_4)_3 + 9 H_2O$	562.00	2—2.1
6	— sulphide	Fe_2S_3	207.86	4.4
7	— thiocyanate	$Fe_2(CNS)_6 + 6 H_2O$	568.23	
8	Ferricyanic acid	$H_3FeC_6N_6$	214.95	
9	Ferrocyanic acid	$H_2Fe(CN)_6$	213.92	
10	Ferropentacarbonyl	$Fe(CO)_5$	195.86	1.46 ; D 6.5
11	Ferroso-ferric oxide	Fe_3O_4	231.52	5.18 cryst.
12	Ferrotetracarbonyl	$Fe(CO)_4$	167.86	1.996/18°
13	Ferrous ammonium sulphate	$FeSO_4(NH_4)_2SO_4 + 6 H_2O$	392.14	1.813
14	— arsenate	$Fe_3(AsO_4)_2 + 6 H_2O$	553.54	
15	— bromide	$FeBr_2 + 6 H_2O$	323.78	
16	— carbonate	$FeCO_3$	115.84	3.7—3.9
17	— chloride	$FeCl_2 + 4 H_2O$	198.82	an. 2.528 ; 1.926
18	— fluoride	$FeF_2 + 8 H_2O$	237.97	
19	— hydroxide	$Fe(OH)_2$	89.86	
20	— iodide	$FeI_2 + 4 H_2O$	381.74	2.873
21	— nitrate	$Fe(NO_3)_2 + 6 H_2O$	287.96	
22	— oxide	FeO	71.84	
23	— perchlorate	$Fe(ClO_4)_2 + 6 H_2O$	362.86	
24	— phosphate	$Fe_3(PO_4)_2 + 8 H_2O$	501.73	2.58—2.68
25	— platinichloride	$FePtCl_6$	463.8	2.714
26	— sulphate	$FeSO_4 + 7 H_2O$	278.01	1.889
27	— sulphide	FeS	87.90	4.84
28	— thiocyanate	$Fe(CNS)_2 + 3 H_2O$	226.04	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
V ; +12 aq. I.	s.	s.	s. alc.	47.2	d.	1
IIIa, Gr.	i.	i.	s. ac.			2
Y.	i.	i.	i.c. acetic	d.		3
B.	i.		d. alk. and oxalic	d.		4
IV.	deliq.	d.	d. alc.	d.		5
Y.	i.	i.	d. ac.	d.		6
I.,R.,or Bl.	red s.	v.s.	s. alc., ether	d.		7
Needles, Gr. Br.	deliq.	s.	s. alc.	d.		8
W. needles	s.		s. alc., i. ether	d.		9
Y.	d.		s. H_2SO_4, alc.	−21	103	10
I., Bl.	i.	i.	i. alc.			11
G. plates			s. org. solv.	d. 140—150		12
V.	19	78/75°	i. alc.	d.		13
W.	i.		s.s. NH_4OH	d.		14
IV., B., G.	s.	56.7/75°	s. alc.	d.		15
IIIa	i.	i.	s. CO_2 soln.	d.		16
V., C.	deliq.	v.s.	s. alc.	R.H.		17
G.B.	s.	s.	s. HF	8 aq 100		18
W.	v.s.s.		s. ac.	d.		19
Gr. cryst.	v.s.	d.	s. alc.	177		20
	s.	d.		d.		21
Bl.	i.	i.	i. alc.	oxidises		22
G.	s.s.			d. >100		23
V., B.	i.	i.	i. ac.			24
III., Y.	v.s.	v.s.		d.		26
IV.; V.; +5 aq. VI; +4 aq. II.	20.4	42.6	i. alc.	6 aq 100 7 aq 280	d. R.H.	25
Bl.	i.	i.	s. ac.	R.H.		27
IV., G.	s.		s. alc.	d.		28

	Name.	Formula	Formula Weight.	Density. Water=1 D : Air=1
1	Fluorine	F	19.0	
2	Gallium	Ga	68.9	5.935—5.956
3	— dichloride	GaCl$_2$	140.82	D :4,8/1000°
4	— sulphate	Ga$_2$(SO$_4$)$_3$	427.98	
5	— trichloride	Ga$_2$Cl$_6$	352.6	D : 6.1/400 —606°
6	Germanium	Ge	72.5	5.469/20.4°
7	— chloroform	GeHCl$_3$	179.9	
8	— dioxide	GeO$_2$	104.5	4.703/18°
9	— disulphide	GeS$_2$	136.6	
10	— monosulphide	GeS	104.6	D :3.54/1100°
11	— tetrachloride	GeCl$_4$	214.3	1.887/18°
12	— tetra-iodide	GeI$_4$	580.2	D :20.5/440°
13	Glucinum	Gl	9.1	2,1
14	— bromide	GlBr$_2$	168.9	
15	— chloride	GlCl$_2$ (+4 H$_2$O)	80,0	
16	— iodide	GlI$_2$	262.9	
17	— nitrate	Gl(NO$_3$)$_2$+3 H$_2$O	187.2	
18	— oxide	GlO	25.1	3,02
19	— sulphate	GlSO$_4$+4 H$_2$O	177,2	1.725/10°
20	Gold	Au	197.2	19,26—19.55
21	Helium	He	3,99	
22	Hydrazine	H$_2$N·NH$_2$	32,05	1.013/15°
23	— di-hydrochloride	N$_2$H$_4$·2HCl	104,99	1.4226/20°
24	— hydrate	H$_2$N·NH$_3$(OH)	50.07	1.0305/21°
25	— sulphate	N$_2$H$_4$,H$_2$SO$_4$.	130,12	
26	Hydrazoic acid	HN$_3$	43.03	
27	Hydriodic acid	HI	127,93	4.375
28	— — hydrate	HI+xH$_2$O (57%)		1.69
29	Hydrobromic acid	HBr	80,93	1.78
30	— — hydrate	HBr+H$_2$O (47.8%)		49
31	Hydrochloric acid	HCl	36.47	0.929/8°
32	— — hydrate	HCl+H$_2$O (45.2%)		1.2257
33	— — —	HCl+8 H$_2$O (20.18%)		1.101
34	Hydrocyanic acid	HCN	27,03	0.6967/18°

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Y.G.	d.			− 233	− 187	1
I., W.	i.	i.	s. alk., HCl	30.1		2
W. cryst.	d.			164	535	3
W.	v.s.		s. alc.			4
W. needles	deliq., d.			75.5	220	5
I., Gr.	i.	i.	s. aq. regia	960	>1350	6
C.	i.	i.		liq.	75	7
W. pdr.	0.4	7.0	s. ac.	d.		8
W. pdr.	0.45		s. KOH			9
IV. or V.	i.	i.	s. KOH, s.s. HCl	R.H.		10
	slow d.			liq.	86	11
P. pdr.	deliq.	d.		144	350—360	12
W.	i.	i.	s. HCl, alk	1278±5		13
W. needles	s.		s. alc.	601	subl.	14
C. cryst.	deliq.	v.s.	s. alc.	600	subl.	15
W. needles	s.		s. alc.	510	590	16
Cryst.	deliq.			60	d. 200	17
O., W.	i.		s. alc.			18
II.; +7 aq., V.	100/15°		2 aq 100		d. R.H.	19
I.			s. aq. regia	1061.0	dist.	20
	0.015			<− 253	− 268	21
Cryst.	s.			1.4	113	22
I.	s.	s.		198		23
C.	m.	v.s.	m. alc.	<− 40	118.5/740	24
Plates.	s.s.	v.s.	i alc.	254		25
	m.		s. alc.	− 80	37	26
	v.s	s.	s. alc.	− 53	− 36.7/752	27
	m.	m.	m. alc.		127	28
	221	130	s. alc.	− 86	− 68.7	29
	m.	m.	s. alc.	− 11	126	30
	82.5/0°	56/60°	327 vol. in alc.	− 112.5	− 83.1/755	31
	m.		s. alc.			32
	m.		s. alc		110	33
	m.	m.	m. alc.	− 13.8	26.1	34

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Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Hydrofluoric acid	HF	20.0	0.9879/15°
2 — hydrate	HF (35.35%)		1.15
3 Hydrofluosilicic acid	H_2SiF_6	144.1	
4 Hydrogen	H	1.008	0.0763/−260°
5 — disulphide	H_2S_2	66.13	1.71
6 — peroxide	H_2O_2	34.016	1.458/0°
7 — selenide	H_2Se	81.2	
8 — sulphide	H_2S	34.08	liq. 0.91/18.5°
9 Hydroxylamine	NH_2OH	33.04	1.227/14°
10 — hydrochloride	$NH_2OH \cdot HCl$	69.50	1.676/17°
11 — nitrate	$NH_2OH \cdot HNO_3$	96.05	
12 — sulphate	$(NH_2OH)_2 \cdot H_2SO$	164.16	
13 Hypobromous acid	HBrO	96.93	
14 Hypochlorous acid	HClO	52.47	
15 Hypophosphorous acid	H_3PO_2	66.06	1.49/10°
16 Indium	In	114.8	7.42
17 — chloride	$InCl_3$	221.2	
18 — oxide	In_2O_3	277.6	7.18
19 — sulphide	In_2S_3	325.8	
20 Iodic acid	HIO_3	175.93	4.629/0°
21 Iodine	I	126.92	4.933
22 — monochloride	ICl	162.38	3.222; D:80.3/120°
23 — pentoxide	I_2O_5	333.84	4.487/0°
24 — trichloride	ICl_3	233.30	3.11
25 Iridium	Ir	193.1	21.15/17.5°
26 — sesquioxide	Ir_2O_3	434.2	
27 — tetrabromide	$IrBr_4$	512.8	
28 — tetrachloride	$IrCl_4$	334.9	
29 — tetra-iodide	IrI_4	700.8	
30 — trichloride	Ir_2Cl_6	599.0	
31 Iron, cast-iron			7—7.6
32 —, wrought-iron }	Fe	55.84	7.25—7.79
33 —, steel			7.6—7.8

Crystalline form and colour	Solubility in 100 parts water at 15°C (60°F)	Solubility in 100 parts water at 100°C (212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
	111/35°	v.s.		−92.3	19.4	1
	v.s.	v.s.			120	2
C.	s.		s.s. alk.		d.	3
	1.93 vol.		alc. 6.925/0°	−257	−253	4
	i.		i	liq.	d.	5
C.	m.		s. ether	−2	84/68 mm.	6
	v.s.		s. $COCl_2$	−64	−42	7
	1 : 3.23 vol. at 15°	1 : 1.86 vol. at 40°	alc. 9.54/15°	−86	61.6	
W. needles	deliq.	d.	i. ether	33	70/60 mm.	9
V.	s.		s.s. alc.	151	d.	10
W.	v.s.	d.	v.s. alc.	−10	d. <100	11
V.	s.	s.	s.s. alc.	140	d.	12
C.	s.	s.			40 in vac.	13
Y.	100 vol./0°	s.	d. HCl		d.	14
	deliq.	v.s.		17.4	d.	15
W.	i.	i.	s. HNO_3	176		16
W.	deliq.				440	17
Y.						18
Br.						19
IV.	187	v.s.		½ aq 170		20
Bl.	v.s.s.	v.s.s.	s. alc.	114	184	21
R.	slight d.		s. HCl	25	d. 101	22
W.	s.	s.		d. 300		23
Y. cryst.	s. d.		s. acetic	101/16atm	d. 25	24
Gr.	i.	i.	i.	2300 ?		25
Bl.	i.			d. 1000		26
B.	s.		s. alc.	d.		27
Bl.	s.	s.d.	s. alc.	d.		28
Bl.	i.	i.	i. ac., s. KI	d. 360		29
Y.G.	i.		i.			30
						31
Gr.	i.	i.	s ac	{ 1050 / 1545 }		32
				1300		33

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Iron carbide	Fe_3C	179.53	
2 — disulphide	FeS_2	119.96	5.185 ; mineral 4.68—4.85
3 — oxide, magnetic	Fe_3O_4	231.52	5.18
4 — phosphide	FeP	142.76	6.57
5 Lanthanum chloride	$LaCl_3$	245.4	3.95/18°
6 — oxide	La_2O_3	326.0	6.48
7 — sulphate	$La_2(SO_4)_3 + 9H_2O$	728.3	
8 Lead	Pb	207.2	11.35—11.387
9 — borate	$Pb(BO_2)_2 + H_2O$	311.0	5.598 an.
10 — bromide	$PbBr_2$	367.0	6.611
11 — carbonate	$PbCO_3$	267.2	6.465
12 — — (white lead)	$2PbCO_3 \cdot Pb(OH)_2$	775.6	
13 — chlorate	$Pb(ClO_3)_2$	374.1	4.037
14 — chloride	$PbCl_2$	278.1	5.8
15 — chlorite	$Pb(ClO_2)_2$	342.1	
16 — chromate	$PbCrO_4$	323.2	6.123/15°
17 — cyanate	$Pb(CNO)_2$	291.2	
18 — cyanide	$Pb(CN)_2$	259.2	
19 — dioxide	PbO_2	239.2	8.9—9.39—9.54
20 — fluoride	PbF_2	245.2	8.241
21 — hydroxide	$(a)\ Pb(OH)_2$	241.2	
22 — —	$(b)\ 3PbO \cdot H_2O$	687.6	
23 — iodide	PbI_2	461.0	6.12
24 — monoxide (massicot)	PbO	223.2	9.29
25 — — (litharge)	PbO	223.2	8.74—9.0
26 — — (amorph.)	PbO	223.2	9.2—9.5
27 — nitrate	$Pb(NO_3)_2$	331.2	4.53/20°
28 — oxychloride	$PbCl_2 \cdot PbO$	501.3	7.21
29 — —	$PbCl_2 \cdot 2PbO$	724.5	7.08
30 — phosphate, ortho	$Pb_3(PO_4)_2$	811.7	6.9—7.3
31 — — pyro	$Pb_2P_2O_7$	588.5	5.8
32 — sesquioxide	Pb_2O_3	462.4	
33 — suboxide	Pb_2O	430.4	
34 — sulphate	$PbSO_4$	303.3	6.2—6.38
35 — — (acid)	$PbH_2(SO_4)_2 + H_2O$	419.4	

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Bl.	i.	i.	i. dil. ac.			1
Y.	i.	i.	s. HNO₃ ppts. S.	d.		2
I., Bl.	i.	i.	i. alc., s. HCl			3
G.	i.	i.	s. ac. and d.	infusible		4
Cryst.	v.s.	v.s.	v.s. alc.	907		5
W. pdr.	gives La(OH)₃					6
C. cryst.	17 (3°)	0.85	s.s. HCl	d.		7
I., Gr.W.	i.		s. HNO₃	327.4	1470	8
W., pdr.	i.	i.	i. alc.	R.H.	aq 160	9
C. needles	s.s.	s.	i. alc.	d. 448		10
IV. W.	0.00198	i.	i. alc., s. ac.	d.		11
Am. W.	i.			d.		12
V., W.	s.	s.		d. 230		13
IV.	0.909	3.2	s. alk.	447	900	14
V., Y.	s.s.	s.		expl.>100		15
V., Y.	i.	i.	s. alk., s.s. ac.	fusible		16
W. needles	s.s.	s.		d.		17
W.	i.		i. KCN soln.			18
III., Br.	i.	i.	i. alc.	d.		19
W.	i.	i.	s. HCl, HNO₃	fusible		20
W.	v.s.s.	v.s.s.	s. alk.	d. 145		21
I., W.				aq 130		22
Y., cryst.	0.081	0.515	i. alc., s. KI	375	861—954	23
IV., Y.	i.	i.	s. alk.	R.H.		24
III., R.	i.	i.				25
Am. Y.				R.H.		26
I. W.	48.4	127	s. alk.	d.		27
II.				d. 524		28
IV. Br.			s. alk.	693		29
W.	i.	i.		fusible		30
IV., W.	i.		s. alk., HNO₃			31
Am. Y.	i.	i.	i. alk.	d.		32
Bl.	d.		d. alk.	d.		33
IV.	0.004	s.s.	i. alc., s. alk.	937		34
Cryst.	v.s.s.			d.		35

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Lead sulphate (basic)	$PbSO_4.PbO$	526.5	
2	— sulphide	PbS	239.3	7.25—7.7
3	— tetrachloride	$PbCl_4$	**349.0**	3.18/0°
4	Lithium	Li	6.94	0.5936
5	— bromide	$LiBr$	86.86	3.464/25°
6	— carbide	Li_2C_2	37.89	1.65/18°
7	— carbonate	Li_2CO_3	73.88	2.111
8	— chlorate	$2LiClO_3 + H_2O$	198.82	
9	— chloride	$LiCl + 2 H_2O$	78.43	2.068/25°
10	— fluoride	LiF	25.94	2.54
11	— hydride	LiH	7.95	
12	— hydroxide	$LiOH$	23.95	
13	— iodide	$LiI + 3 H_2O$	187.91	3.48
14	— nitrate	$LiNO_3$	68.95	2.334/92.5°
15	— oxide	Li_2O	29.88	2.10/15°
16	— perchlorate	$LiClO_4 + 3 H_2O$	160.45	
17	— phosphate	$2Li_3PO_4 + H_2O$	249.74	2.41
18	— platinichloride	$Li_2PtCl_6 + 6 H_2O$	529.9	
19	— sulphate	$Li_2SO_4 + H_2O$	127.96	2.02
20	— sulphite	$Li_2SO_3 + H_2O$	111.96	
21	Magnesium	Mg	24.32	1.75
22	— bromate	$Mg(BrO_3)_2 + 6 H_2O$	388.26	2.29
23	— bromide	$MgBr_2 + 6 H_2O$	292.26	
24	— carbonate	$MgCO_3$	84.32	3.056
25	— — (basic)	$3MgCO_3.Mg(OH)_2 + 3 H_2O$	365.37	2.18
26	— chlorate	$Mg(ClO_3)_2 + 6 H_2O$	299.34	
27	— chloride	$MgCl_2 + 6 H_2O$	203.34	1.558/17°
28	— fluoride	MgF_2	62.32	2.97
29	— hydrogen phosphate	$MgHPO_4 + 7 H_2O$	246.48	
30	— hydroxide	$Mg(OH)_2$	58.34	2.34
31	— iodate	$Mg(IO_3)_2 + 4 H_2O$	446.22	3.28
32	— iodide	MgI_2	278.14	
33	— nitrate	$Mg(NO_3)_2 + 6 H_2O$	256.44	1.46
34	— oxide	MgO	40.32	3.36 cryst.; 3.58 am.

Crystalline form and colour	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
W.	1 :22816	v.s.s.	s.s. H_2SO_4	d.		1
I.	i.	i.	i. alc.	R.H.	subl.	2
	d.			-15	d. 105	3
	d.		d. alc.	186	>950	4
Cryst.	143/0°	270/103°		442		5
W. pdr.	d.					6
W.	1.37	0.728	i. alc.	618		7
II.	deliq.		v.s. alc.	50	aq 90	8
II., an. I.	76.5	125	v.s. alc.	606	d. W.H.	9
C.	0.27 (14°)			R.H.		10
W.	d.			680		11
W.	s.s.			R.H.		12
V.	164	476		72	aq 120	13
IIIa	55.2	227.3	v.s. alc.	258		14
W.	5 (0°)	s.		vol. 600		15
IIIa	deliq.	s.	s. alc.	2 aq 100 / 3 aq 150		16
	0.04		s. ac.			17
III., Y.	s.	s.	s. alc.	aq 180		18
V.	34.6/18°	29.2	s. alc.	an. 853		19
Needles	s.		s.s. alc.	R.H.		20
W.	i.	d. steam	s. ac.	750	1100	21
I.	71.4			6 aq 200	d.	22
III.	103.4 (18°)	v.s.		165	d.	23
IIIa, IV	i.	i.	s. CO_2 soln.	d. 350		24
V.	v.s.s.	v.s.s.		d.		25
W. cryst.	deliq.	s.	s. alc.	40	d. 120	26
V.	54	v.s.	s. alc.	d. >186		27
II.	0.076/18°		i. ac.			28
III.	s.s.		s. ac.	4 aq 100		29
IIIa	0.0009(18°)		s. NH_4Cl	d.		30
V.	10.6	33		4 aq 210	d.	31
W. cryst.	148 (18°)		s. alc.	fusible		32
V., VI.	73.4 (18°)		s. alc.	90,5 aq 100	d.	33
I.	s.		s. alc.	2250		34

	Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1	Magnesium pyrophosphate	$Mg_2P_2O_7+3H_2O$	276.77	2.56
2	— sulphate (epsomite)	$MgSO_4+7H_2O$	246.50	1.678/16°
3	—— (kieserite)	$MgSO_4+H_2O$	138.40	2.35
4	— sulphide	MgS	56.38	2.85 cryst.; 2.2 am.
5	— sulphite	$MgSO_3+6H_2O$	212.48	
6	Manganese	Mn	54.93	8.0
7	— dioxide	MnO_2	86.93	4.82
8	— heptoxide	Mn_2O_7	221.86	
9	— tetrachloride	$MnCl_4$	196.77	
10	— tetrafluoride	MnF_4	130.93	
11	— trioxide	MnO_3	102.93	
12	Manganic meta-phosphate	$Mn_2(PO_3)_6+2H_2O$	620.13	4.75 cryst.;
13	— oxide	Mn_2O_3	157.86	4.32 am.
14	—— hydrated	$Mn_2O_2(OH)_2$	175.88	4.33
15	— sulphate	$Mn_2(SO_4)_3$	398.04	
16	Mangano-manganic oxide	Mn_3O_4	228.79	4.72–4.85 cryst.
17	Manganous carbonate	$MnCO_3$	114.93	3.45–3.60 nat.
18	— chloride	$MnCl_2+4H_2O$	197.91	1.91
19	— hydroxide	$Mn(OH)_2$	88.95	3.26
20	— iodide	MnI_2+4H_2O	380.83	
21	— nitrate	$Mn(NO_3)_2+6H_2O$	287.05	1.82/21°
22	— oxide	MnO	70.93	5.09
23	— sulphate	$MnSO_4+4H_2O$	223.05	2.107/4°
24	— sulphate	$MnSO_4+7H_2O$	277.10	3.1 an.
25	— sulphide	$MnS(+H_2O)$	87.00	4.04
26	Mercuric acetylide	$3C_2Hg,H_2O$	691.8	5.3

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Am. W.	i.	i.	i. alc.	5 aq 150		1
IV., V.	33.8	73.8	s. alc	6 aq 150 / 7 aq 200		2
IV.	v.s.s.	s.				3
Am. Br	s.s.	d.		d.		4
III.	1.25	0.83		6 aq 260		5
Gr	slow d.	d.	s. ac.	1225		6
IV., Gr.	i.	i.	with HCl : Cl	d. 390		7
Bl.	s. d.		s. H_2SO_4	liq.	expl. 70	8
	s. to green	s.	s. ether			9
	s. to brown	d.				10
Bl.	$HMnO_4$		s. alk.	liq.	50	11
V.	s.s.	s.				12
II., Br.	i.	i.	i. acetic			13
II., Bl. Br.	i.	i.	s. ac.	to Mn_3O_4		14
G.	d.			d. 160		15
II., R.	i.	i.	s. ac. d.			16
IIIa. P.	i.	i.	i. alc., s. ac.	d.		17
V., P.	107 (10°)	116	s. alc.	2 aq 58 / 4 aq 198		18
W.	i.	i.	s. ac.	d.		19
C. needles	deliq.	v.s.				20
V., W.	v.s.	v.s.	s. alc.	+6 aq 25.8 / +3 aq 35.5	d. 230	21
I., G.	i.	i.	s. ac.	W.H.		22
V	63.8	52.9	i. alc.	stable 18—30		23
IV., V.	64.3	33.2	i. alc.	54 / an. 400	5 aq 120 / 6 aq 200	24
I., G. : Am. F	i.	i.	s. alc.	fusible		25
W. pdr.	i.	i.	i. alc.	expl.		26

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Mercuric bromide	$HgBr_2$	360.4	5.7
2 — chloride	$HgCl_2$	271.5	5.403 ; D : 9.8
3 — cyanide	HgC_2N_2	252.6	3.99—4.02
4 — iodide	HgI_2	454.4	6.26
5 — potassium iodide	$2KHgI_3 (+3 H_2O)$	1294.9	4.25
6 — nitrate	$Hg(NO_3)_2$	324.6	
7 — oxide	HgO	216.6	11.136/4°
8 — sulphate	$HgSO_4 (+2 H_2O)$	296.7	6.47
9 — — (basic)	$HgSO_4 + 2 HgO$	729.9	6.444
10 — sulphide	HgS	232.7	8.124
11 Mercurous bromide	Hg_2Br_2	561.0	7.037
12 — carbonate	Hg_2CO_3	461.2	D. 3.92/218°
13 — chloride	Hg_2Cl_2	472.1	6.48
14 — chromate	Hg_2CrO_4	517.2	
15 — iodide	Hg_2I_2	655.0	7.644
16 — nitrate	$Hg_2(NO_3)_2$	525.2	liq. : 4.3/70°
17 — oxide	Hg_2O	417.2	8.95
18 — sulphate	Hg_2SO_4	497.3	7.12 ppd.
19 Mercury	Hg	200.6	13.59 ; D : 6.93/18.5°
20 Microcosmic salt	$NH_4NaHPO_4 + 4 H_2O$	209.15	1.55
21 Molybdenum	Mo	96.0	9.01
22 — dichloride	$MoCl_2$	166.9	
23 — dioxide	MoO_2	128.0	6.44/16°
24 — disulphide	MoS_2	160.1	4.88
25 — hexafluoride	MoF_6	210.0	
26 — pentachloride	$MoCl_5$	273.2	D : 9.5/350°
27 — tetrasulphide	MoS_4	224.2	
28 — trioxide	MoO_3	144.0	4.39/21°
29 — trisulphide	MoS_3	192.2	
30 Molybdic acid	$H_2MoO_4 + 4 H_2O$	234.08	
31 Nickel	Ni	58.68	8.8—8.9
32 — bromide	$NiBr_2 + 3 H_2O$	272.57	
33 — chloride	$NiCl_2$	129.60	2.56

Crystalline form and colour	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
		Solubility*in				
IV., W.	0.4		s. alc.	244	319	1
IV.	5.6	55.7	33 alc. 25 ether s. NaCl aq.	287	303—307	2
Il.	12	53.8	5 alc.	d.		3
II., R.; IV., Y.	0.003	s.s.	0.8 alc.	241	349	4
Y.	s. forms basic salt	s.	s. alc., acetic	d.		5
			s. HNO₃	79	d. R.H.	6
R. & Y.	0.005	v.s.s.	i. alc.	d. R.H.		7
W.	forms basic salt		i. alc.	d. R.H.		8
Y.	0.05	0.33	i. alc.	turns red		9
IIIa, R.; Am Bl.	i.	i.	s. aqua regia.	subl.		10
II., W.	i.	i.		subl. 350		11
Y.	i.	i.	i. alc.	d. 130		12
IV., W.	i.	i.	i. alc.	302	subl.	13
R. needles	i.	i.	i. alc.	d.		14
IV., G.	s.s.	i.	i. alc.	290	310	15
2 aq. V.	forms basic salt		s. dil. HNO₃	70	d.	16
Bl.	i.	i.	i. alc.			17
V.	v.s.s.	d.	s. hot. H₂SO₄	d.		18
W.	i.		s.HNO₃,H₂SO₄	−38.9	357.25	19
V.C.	16	100	i. alc.	d.		20
W.			s.HNO₃, i. HCl	2420—2480		21
Y.	i.	i.	s. alc., s. HCl	subl.		22
II., Br. Bl.	i.	i.	i. aq. KOH			23
Bl. pdr.						24
W. cryst.	d.			17	35	25
Bl.	d.		s. alc., s. HCl	194	268	26
Br.	i.		s. KHS			27
IV., W. pd	0.2	0.1	s. NH₄OH	759	d.	28
Br.	s.s.		s. KHS	d.		29
Y.	s.		s. ac.			30
W.	i.		s. ac.	1452		31
Needles	deliq.	v.s.				32
Y.	s.	s.	s. alc.	subl.		33

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Nickel chloride, hydrate	$NiCl_2 + 6 H_2O$	237.70	
2 Nickelic hydroxide	$Ni_2(OH)_6$	219.41	
3 Nickel nitrate	$Ni(NO_3)_2 + 6 H_2O$	290.80	2.065/14°
4 — phosphate	$Ni_3(PO_4)_2 + 7 H_2O$	492.23	
5 — cyanide	NiC_2N_2	110.71	
6 — hydroxide	$Ni(OH)_2$	92.70	4.36
7 — oxide	NiO	74.68	6.4—6.8
8 — phosphide	Ni_3P_2	238.12	5.99
9 — sesquioxide	Ni_2O_3	165.36	4.846
10 — sulphide	NiS	90.74	
11 — sulphate	$NiSO_4$	154.74	3.418
12 ——, hydrate	$NiSO_4 + 6 H_2O$	262.84	2.031
13 ——, hydrate	$NiSO_4 + 7 H_2O$	280.86	1.98
14 — tetra-carbonyl	$Ni(CO)_4$	170.70	1.3185/17°
15 Nitric acid	HNO_3	63.02	1.54/0°
16 ——, hydrate	$HNO_3 + 32\% H_2O$		1.414/15.5°
17 — oxide	NO	30.01	0.00135
18 Nitrogen	N	14.01	liq.:0.804/ −199.5°
19 — iodide	$N_2H_3I_3$	411.80	3.5
20 — pentasulphide	N_2S_5	188.32	1.901/18°
21 — pentoxide	N_2O_5	108.02	1.64/18°
22 — sulphide	N_4S_4	184.28	2.22
23 — tetroxide	N_2O_4	92.02	liq.:1.4903/0°
24 — trichloride	NCl_3	120.39	1.65
25 — trioxide	N_2O_3	76.02	liq:1.447/ −2°
26 Nitrous oxide	N_2O	44.02	liq:1.226/ −89.4°
27 Nitrosyl bromide	$NOBr$	109.93	<H_2O
28 — chloride	$NOCl$	65.47	1.425/ −15°
29 Nitrosylsulphuric acid	$NO \cdot SO_2 \cdot OH$	111.08	
30 — anhydride	$(SO_2 \cdot NO_2)_2 O$	236.14	
31 Nitroxyl chloride	NO_2Cl	81.47	1.316/14°
32 Osmium	Os	190.9	22.479
33 — monoxide	OsO	206.9	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
III.	s.	s.	s. alc.			1
Bl.	i.	i.	s.ac.,NH$_4$OH			2
V. G.	50	v.s.	s. alc.	56.7	136.7	3
G.	i.	i.	s. ac.			4
	i.	i.	s. KCN			5
G.	i.	i.	s.ac.,NH$_4$OH			6
I. Gr.Bl. G	i.		s. NH$_4$OH			7
G. Bl.	i.	i.	i. HCl			8
Bl.			s. HCl reduc.	d.		9
III., Bl. G$_1$	i.		s.s.ac.,s.KHS			10
Y.	36.5	61.9 (70°)	i. alc.			11
II. Bl.,V.G	s.	s.	s. NH$_4$OH	6 aq 280		12
IV. G.	36.5	83.7		6 aq 103		13
C.	0.018 (9.8°)		s. alc.	− 25	43.2	14
	m.	m.	d. alc.	− 40.3	86	15
	m.	m.	d. alc.	liq.	120.5	16
	1 : 20 vol.	v.s.s.	s. FeSO$_4$ soln.	< − 167	− 153	17
	0.0235 : 1 vol. (4°)			− 210	− 199.5	18
dark R.	s.s. d.			expl.		19
R.	i.		s.s. CS$_2$, alc.	10—11	d.	20
IV.	s.	s.	d. alc.	30	d. 47	21
R. prism.	i.		s CS$_2$	subl. 135	d. >178	22
	d.			− 10.1	26	23
IV.	i. d.		s. org. solv.	liq.	expl. 95	24
R.	s.	d.	d.	− 111	d. 3.5	25
	0.7778 : 1 vol.	s.s.	s.s. alc.	− 103.7	− 89.4/741mm.	26
Br.	d.			liq.	d. − 2	27
Y.	d.			− 60	− 5.6/751mm.	28
IV.	d.		s. H$_2$SO$_4$	73		29
II.	d.		s. H$_2$SO$_4$	217	360	30
Y.	d.			liq.		31
I. W. Viol.	i.			2700		32
Gr. Bl.	i.	i.	i. ac.			33

	Name	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Osmium tetrachloride	$OsCl_4$	332.7	
2	— tetroxide	OsO_4	254.4	
3	Oxygen	O	16.00	liq :1,118/ − 182.5°
4	Ozone	O_3	48.00	
5	Palladious bromide	$PdBr_2$	266.5	
6	— chloride	$PdCl_2+2 H_2O$	213.7	
7	— cyanide	PdC_2N_2	158.7	
8	— iodide	PdI_2	360.5	
9	— sulphate	$PdSO_4+2 H_2O$	238.8	
10	Palladium	Pd	106.7	11.4/22.5°
11	— hydrogen			11.06
12	— subsulphide	Pd_2S	245.5	7.36/15°
13	Perchloric acid	$HClO_4$	100.47	1.76/22°
14	——, hydrate	$HClO_4+H_2O$	118.49	1.811
15	——, dihydrate	$HClO_4+2 H_2O$	136.51	1.7
16	Per-iodic acid	H_5IO_6	227.96	
17	Persulphuric acid	$H_2S_2O_8$	194.14	
18	Phosgene, *see* Carbonyl chloride			
19	Phospham	PHN_2	60.07	
20	Phosphomolybdic acid	$H_3PO_4 \cdot 12MoO_3+12 H_2O$	2042.3	
21	Phosphonium bromide	PH_4Br	114.99	
22	— chloride	PH_4Cl	70.53	
23	— iodide	PH_4I	161.99	
24	Phosphoretted hydrogen, gas.	PH_3	34.06	
25	——, liq.	P_2H_4	66.11	1,016
26	——, solid	P_4H_2	126.18	
27	Phosphoric acid, meta	HPO_3	80.05	
28	——, ortho	H_3PO_4	98.06	liq. :1.88
29	——, pyro	$H_4P_2O_7$	178.11	
30	Phosphorous acid	H_3PO_3	82.06	1.65/21°
31	Phosphorus, white	P	31.04	1.836/0°
32	—, red	P	31.04	2.16

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
R.	v.s.	s.	s. HCl, alc.			1
V. C.	s.	s.	- alk., alc.	20	100	2
	4.89 vol./0°	i.	alc. 28.4 vol./0°	-230	-182.5	3
	v.s.s.		s. eth. oils	d. 270	-119	4
Br.	i.	i.	s. HBr			5
Bl., R.	s.	s.	s. HCl	R.H. & d.		6
Y.	i.	i.	s.KCN,NH$_4$OH	d.		7
Bl.	i.	i.	s. alc., KI	d. 100		8
R.	v.s.	v.s.				9
W.Gr.			s. HCl, HNO$_3$	1549	2300	10
				d.		11
Gr.	i.	i.	i. ac.	R.H.		12
	s.	s.		-35 liq.	39/56 mm.	13
Cryst.	s.	s.		50	expl. 110	14
	m.	s.		liq.	203	15
	s.			d. 133		16
	s.	d.				17
						18
W. pdr.		i.	i.	infusible		19
V. Y.	s.			aq 104		20
I. C.	d.		d.		30	21
I.	d.			26	subl.	22
II. C.	d.		d.	subl.	80	23
	s.s.	i.		-133.5	-85	24
C.	i.	i.		<-10	57/735 mm	25
Y.	i.	i.		ignites 160	d.	26
Glassy	s.	s.		Volatile bright R.H.		27
IV.	deliq.	v.s.	s. alc	38.6	aq 160 and 290	28
	v.s.	v.s.	v.s.	61		29
C., cryst.	v.s.	v.s.		70.1	d. 200	30
I. C.	i.	i.	s. CS$_2$	44.2	290	31
Am., R.Br.	i.		i. CS$_2$			32

	Name	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Phosphorus, black	P	31.04	2.34
2	— di-iodide	P_2I_4	569.76	
3	— oxybromide	$POBr_3$	286.80	2.822
4	— oxychloride	$POCl_3$	153.42	D : 5.334/151°; 1.69/5°
5	— oxyfluoride	POF_3	104.04	3.7
6	— pentabromide	PBr_5	430.64	
7	— pentachloride	PCl_5	208.34	D : 3.60/296°
8	— pentafluoride	PF_5	126.04	
9	— pentaselenide	P_2Se_5	458.08	
10	— pentasulphide	P_2S_5	222.38	
11	— pentoxide	P_2O_5	142.08	2.387
12	— tribromide	PBr_3	270.80	2.925/0°
13	— trichloride	PCl_3	137.42	1.6129/0°
14	— tri-iodide	PI_3	411.80	
15	— trioxide	P_2O_3	110.08	liq : 1.936/25°; solid : 2.135/21
16	Phosphoryl imidoamide	$PO(NH)(NH_2)$	78.08	
17	— nitride	PON	61.05	
18	— triamide	$PO(NH_2)_3$	95.12	
19	Platinic bromide	$PtBr_4$	514.9	
20	— chloride	$PtCl_4 + 5 H_2O$	427.1	
21	— hydroxide	$Pt(OH)_4$	263.2	
22	Platinous bromide	$PtBr_2$	355.0	
23	— chloride	$PtCl_2$	266.1	5.87
24	— cyanide	PtC_2N_2	247.2	
25	— hydroxide	$Pt(OH)_2$	229.2	
26	— iodide	PtI_2	449.0	
27	Platinum	Pt	195.2	21.4
28	— dioxide	PtO_2	227.2	
29	— disulphide	PtS_2	259.3	7.224
30	— monosulphide	PtS	227.3	
31	— monoxide	PtO	211.2	
32	Potassamide	KNH_2	55.12	

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkaliés	M.P. °C.	B.P. °C.	
IIIa	i.	i.	i. CS$_2$			1
Y.R. cryst.	d.		s. CS$_2$	110	..	
Cryst.	d.		s. H$_2$SO$_4$	55—56	195	3
	d.		d.	−1.5	110	4
C.	d.			−68	−40	5
Y. cryst.	d.		d.	<100	d. 100	6
II,W.cryst	d.		i. CS$_2$	148 under pressure	subl. 162	7
	d.			−83	−75	8
Bl.	d.		i. CS$_2$, s. CCl$_4$	d.		9
Y. cryst.	d.		s. CS$_2$	275	530	10
Am. W.	deliq.	d.		subl R.H.		11
C.	d.		d.	−41.5	175	12
C.	i.l.		s. CS$_2$	−112	76	13
R. cryst.	d.		s. CS$_2$	55	d.	14
Am., W.	d.		s. CS$_2$, C$_6$H$_6$	22.5	173.1	15
Am. W.	i.	d.		d.		16
Am. W.	i.	i.		R.H.		17
Am. W.	i.	i.	s. alc., i. ac.	d.		18
Br.	s.s.	s.s.	s. alc.			19
V. R.	s.	v.s.	s. alc.	d.		20
Br.			s. ac., KOH			21
G.	i.	i.	s. HBr		d. 200	22
Gr.G.	i.	i.	s. HCl	d.		23
Y.Br.	i.	i	i. alc.			24
Bl.			s. HCl			25
Bl.	i.		s. ac., KOH	d. 350		26
	i.		s. HCl+HNO$_3$	1755		27
Bl.						28
Gr.Bl.	i.		s. HCl, HNO$_3$	d.		29
Bl.	i		. ac.			30
Gr.				d.		31
Y.Gr.	d.			270—272	subl. 400	32

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Potassium	K	39.10	D : 3.1/1040°; 0.8650/15°
2 — aluminate	K_2AlO_4	196.4	
3 — antimonate	$KSbO_3$	207.3	
4 — arsenate	K_3AsO_4	256.26	
5 — —	K_2HAsO_3	202.17	
6 — aurate	$AuO \cdot OK + 3\,H_2O$	322.4	
7 — aurichloride	$AuCl_3 \cdot KCl + 2\,H_2O$	414.2	
8 — auricyanide	$AuC_3N_3 \cdot KCN + H_2O$	358.4	
9 — aurocyanide	$AuCN \cdot KCN$	288.3	
10 — bicarbonate	$KHCO_3$	100.11	2.25
11 — bisulphate	$KHSO_4$	136.17	2.163
12 — bisulphite	$KHSO_3$	120.17	
13 — borofluoride	KBF_4	126.0	2.51/20°
14 — bromate	$KBrO_3$	167.02	3.271/17.5°
15 — bromide	KBr	119.02	2.681/15°
16 — carbonate	K_2CO_3	138.2	2.267
17 — carbonyl	$K_6C_6O_6$	402.63	
18 — chlorate	$KClO_3$	122.56	2.34/17°
19 — chloride	KCl	74.56	1.995/15°
20 — chromate	K_2CrO_4	194.2	2.7
21 — chromicyanide	$K_3Cr(CN)_6$	325.4	
22 — cobalticyanide	$K_3Co(CN)_6$	332.36	1.906
23 — cobaltinitrite	$K_3Co(NO_2)_6$	452.93	
24 — cobalt sulphate	$K_2SO_4 \cdot CoSO_4 + 6\,H_2O$	437.89	2.154/40°
25 — cyanate	$KCNO$	81.12	2.048
26 — cyanide	KCN	65.12	1.52/16°
27 — dichromate	$K_2Cr_2O_7$	294.2	2.69/4°
28 — dihydrogen phosphate	KH_2PO_4	136.16	2.3
29 — disulphate	$K_2S_2O_7$	254.32	2.27
30 — dithionate	$K_2S_2O_6$	238.32	2.28
31 — ferric sulphate	$K_2SO_4 \cdot Fe_2(SO_4)_3 + 24\,H_2O$	1006.60	
32 — ferricyanide	$K_6Fe_2(CN)_{12}$	658.46	1.82/17°
33 — ferrocyanide	$K_4Fe(CN)_6 + 3\,H_2O$	422.38	1.85/17°

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
II., W.	d.		d. alc.	62.5	720	1
	s.					2
	i.	d.				3
Needles	18.87	v.s.	s. alc.			4
	v.s.	v.s.				5
Y. needles	s.	v.s.				6
IV. plates	s.	s.				7
C.-	s.	s.	i. alc.			8
IV. C.	14.3	200				9
V.	25.07	83.0	alc. h. 0.083	d.		10
IV, V.	v.s.	v.s.		197	d.	11
W. needles	s.	s.	i. alc.	d. 190		12
W. cryst.	s.		s. alc.			13
IIIa.	6.667	49.75	s.s. alc.	d. 703		14
I.	63.0	102.0	alc. 0.5	745	sub. W.H.	15
V.	109	156	i. alc.	880	d. 810	16
Gr.R.	expl.		d. alc.	expl.		17
V.	6.0	56.5	alc. 0.833	370	d. 400	18
I.	33.4	56.6	alc. 0.5	770	subl W.H.	19
IV., Y.	61.9	79.1	i. alc.	R.H.		20
V., Y.	i.	i.	s. ac., alk.	3 aq in vac 4 aq 100		21
	v.s.	v.s.	i. alc.	d.		22
Y. prism.	s.s.	s.s.	i. alc.			23
V. plates	32.5	v.s.				24
B. needles	s.		s. alc.			25
I.	v.s.		v.s.s. alc.	R.H.	R.H.	26
VI., R.	9.9	94.1	i. alc.	400	d.	27
II.	v.s.		i. alc.	d.		28
Needles	s.	d.		210	d.	29
III. C.	6	75	i. alc.	d.		30
I. Viol.	20	v.s.				31
V. R.	40	80	i. alc.	d.		32
V. Y.	28	100	i. alc	3 aq 60—8(		33

Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1 Potassium fluoride	$KF + 2 H_2O$	94.1	2.454
2 — hydride	KH	40.11	
3 — hydrogen phosphate	K_2HPO_4	174.25	
4 — — sulphide	KHS	72.17	
5 — hydroxide	KOH	56.11	2.044
6 — hypochlorite	$KClO$	90.56	
7 — hypophosphite	KH_2PO_2	104.16	
8 — iodate	KIO_3	214.02	3.97/18°
9 — iodide	KI	166.02	D:5.5/1320°; 3.04/24°
10 — iodotetrachloride	$KICl_4$	307.86	
11 — magnesium chloride	$KCl, MgCl_2 + 6 H_2O$	277.90	1.618
12 — manganate	K_2MnO_4	197.13	
13 — manganic sulphate	$K_2SO_4 \cdot Mn_2(SO_4)_3 + 24 H_2O$	1004.78	
14 — manganicyanide	$K_6Mn_2(CN)_{12}$	656.64	
15 — mangonocyanide	$K_8Mn_2(CN)_{12} + 6 H_2O$	842.94	
16 — metabisulphite	$K_2S_2O_5$	222.32	
17 — molybdate	K_2MoO_4	238.2	
18 — nickel sulphate	$K_2SO_4 \cdot NiSO_4 + 6 H_2O$	437.10	2.124
19 — nitrate	KNO_3	101.11	2.087/15°
20 — nitrite	KNO_2	85.11	
21 — oxide	K_2O	94.20	2.656
22 — palladichloride	K_2PdCl_6	397.7	2.8
23 — palladochloride	K_2PdCl_4	326.7	2.738
24 — pentasulphide	K_2S_5	238.50	
25 — perborate	KBO_3	98.0	
26 — perchlorate	$KClO_4$	138.56	2.54
27 — periodate	KIO_4	230.02	
28 — permanganate	$KMnO_4$	158.03	2.70/10°
29 — peroxide	K_2O_4	142.20	
30 — persulphate	$K_2S_2O_8$	270.32	
31 — phosphate, meta	KPO_3	118.14	2.26
32 — —, ortho	K_3PO_4	212.34	
33 — —, pyro	$K_2P_2O_7 + 3 H_2O$	306.93	2.33
34 — platinibromide	K_2PtBr_6	752.9	4.541

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
I.	deliq.	v.s.	s.s. alc.	an. 885		1
W. needles	d.		reacts C$_2$H$_2$	burns in F Cl and O		2
	deliq.	v.s.	v.s. alc.	d.		3
IIIa, C.	s.	s.	s. alc.	455		4
+2aq.,IIIa	200	v.s.	s. alc.	R.H.	subl. W.H.	5
Needles	v.s.	v.s.	...	d.		6
III.	deliq.			d.		7
I.	7.2	32	i. alc.	560	d.	8
I.	140	209	alc. 2.5	685	723	9
V.	d.		—	d.		10
III., C., R.	64.5 (18.8°)	d.		R.H.		11
V., G., Bi.	s.	d.	s. alk.			12
I., Viol.	d.					13
R.	s.					14
II. B.	s.					15
V. plates	s.	d.	s.s. alc.	d.		16
Micro cryst.	s.	s.				17
V. B.	11.3	45.6 (75°)				18
IV., IIIa	26	247	i. alc.	334, 340	d.	19
	deliq.	v.s.	s. alc.			20
Gr.	v.s.	v.s.	v.s. alc.	R.H.		21
I. R.	s.s.	d.	i. alc.	d.		22
	s.	s.	s.s. alc.	d.		23
Y.Br.	v.s.	v.s.	v.s. alc.	abt. 220°		24
V.	v.s.	v.s.				25
IV.	1.667	18.18	i. alc.	610		26
IV.	0.345	s.		582		27
IV. R.Bl.	6.45	v.s.	d.	d. 240		28
Y.	d.		alc. d.	R.H.	d. W.H.	29
VI.	1.76	d.		d.		30
Am. W.	i.		s. ac.	infusible		31
IV.	s.		i. alc.			32
	s.	v.s.		aq 100, 180, 300		33
I., R.	2	i0				34

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Potassium platinichloride	K_2PtCl_6	486.2	3.344
2 — platinobromide	K_2PtBr_4	593.1	
3 — platinochloride	K_2PtCl_4	415.2	3.3/20°
4 — platinocyanide	$K_2Pt(CN)_4 + 3 H_2O$	431.5	2.52
5 — plumbate	$K_2PbO_3 + 3 H_2O$	387.45	
6 — selenate	K_2SeO_4	221.4	3.0657/20°
7 — silicate	K_2SiO_3	154.3	
8 — silicofluoride	K_2SiF_6	220.3	2.66
9 – silver cyanide	$KCN\,AgCN$	199.00	
10 — sodium carbonate	$KNaCO_3 + 6 H_2O$	230.20	1.61
11 — stannate	K_2SnO_3	244.9	3.197
12 — sulphate	K_2SO_4	174.26	2.66/20°
13 — sulphide	K_2S	110.26	2.13
14 — sulphite	$K_2SO_3 + 2 H_2O$	194.30	
15 — tetraborate	$K_2B_4O_7 + 5 H_2O$	324.3	1.74
16 — tetrasilicate	$K_2Si_4O_9$	334.6	
17 — thiocyanate	$KCNS$	97.18	1.91
18 — thiosulphate	$K_2S_2O_3 + H_2O$	208.34	
19 — tri-iodide	KI_3	419.86	3.498
20 Red lead	Pb_3O_4	685.6	8.62
21 Rhodium	Rh	102.9	12.1
22 — cæsium alum	$Rh_2(SO_4)_3 Cs_2SO_4 + 24 H_2O$	1228.1	
23 — chloride	$RhCl_3 + 4 H_2O$	281.3	
24 — nitrate	$Rh_2(NO_3)_6 + 4 H_2O$	649.9	
25 Rubidium	Rb	85.45	1.5220/15°
26 — bromide	$RbBr$	165.37	2.78
27 — carbonate	Rb_2CO_3	230.90	
28 — chlorate	$RbClO_3$	168.91	
29 — chloride	$RbCl$	120.91	2.2
30 — hydride	RbH	86.46	2.0
31 — hydroxide	$RbOH$	102.46	
32 — iodide	RbI	212.37	3.02—3.44
33 — nitrate	$RbNO_3$	147.46	3.131

Crystalline form and colour	Solubility in 100 parts water at 15°C(60°F)	Solubility in 100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
I., Y.	0.92	5.26		d.		1
IV., Bl.	v.s	v.s.				2
II. R.	s.	s.	i. alc.			3
IV. Y.	deliq.	s.	s. H_2SO_4, alc.	an. 100	d. R.H.	4
II. C.	d.		s. KOH			5
IV.	115 (12°)					6
Am.	s.	s.				7
I.	0.126	2	i. alc.	d. R.H.		8
W.	12.5	100	4 alc.			9
V.	20				6 aq 100	10
V. C.	s.	s.	s.s. KOH			11
IV.	10.3	26.2	i. alc.	1070	subl.	12
P.	v.s.	v.s.	s. alc.			13
IV.	100	v.s.	i. alc.	d.		14
III.	v.s.	v.s.		5 aq R.H.		15
Am.	s.	s.	i. alc.			16
	217 (20°)	v.s.	s. alc.	161		17
V.	v.s.	v.s.	i. alc.	aq 200		18
Prism.	d.		s. KI soln., alc	45	d.	19
R.	i.	i.	i. alc.	d. >400		20
W.			s.s. ac., s. fus. $KHSO_4$	1920		21
Y. oct.	s.s.			110—111		22
R.	s.		s. alc.			23
P.	s.	s.	i. alc.			24
W.	d.			38.5	R.H.	25
W.	98 (5°)	105 (16°)				26
C.	deliq.	v.s.		837	d. 740	27
W.	3 (5°)	5 (19°)				28
I. C.	82.9 (7°)			710		29
C. needles				d. 300 in vac		30
W.	1.18 (25°)	11.76	s. alc.	<R.H.		31
	137 (7°)	152 (18°)		R.H.		32
III. needle	19.5 (0°)	452	v.s. HNO_3			33

	Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1	Rubidium perchlorate	RbClO$_4$	184.91	
2	— platinichloride	Rb$_2$PtCl$_6$	578.9	
3	— sulphate	Rb$_2$SO$_4$	266.96	3.64
4	Ruthenium tetroxide	RuO$_4$	165.7	liq>H$_2$SO$_4$
5	Selenic acid	H$_2$SeO$_4$(+xH$_2$O)	145.2	2.95/15°
6	Selenious acid	H$_2$SeO$_3$	129.2	3.01/15.7°
7	Selenium, metal.	Se	79.2	4.80
8	—, cryst.	Se	79.2	4.5
9	—, amorph.	Se	79.2	D:5.68/1400°; 4.26/20°
10	— dioxide	SeO$_2$	111.2	3.95/15°
11	— monobromide	Se$_2$Br$_2$	318.2	3.604/15°
12	— monochloride	Se$_2$Cl$_2$	229.3	2.91/17°
13	— mono-iodide	Se$_2$I$_2$	412.2	
14	— monosulphide	SeS	111.3	3.056/0°
15	— nitride	Se$_2$N$_2$	186.4	
16	— oxychloride	SeOCl$_2$	166.1	2.44
17	— potassium cyanide	KCN·Se	144.3	
18	— tetrabromide	SeBr$_4$	398.9	
19	— tetrachloride	SeCl$_4$	221.0	
20	— tetra-iodide	SeI$_4$	586.9	
21	Silica	SiO$_2$	60.1	Cryst. 2.66; amorph. 2.2/16°
22	Silicic acid (meta)	H$_2$SiO$_3$	78.1	2.324
23	Silico-bromoform	SiHBr$_3$	268.9	2.7
24	— chloroform	SiHCl$_3$	135.5	1.344
25	— iodoform	SiHI$_3$	409.9	3.4
26	Silicon, cryst.	Si	28.1	2.49
27	— carbide	SiC	40.1	3.22/15°
28	— disulphide	SiS$_2$	92.2	
29	— tetrabromide	SiBr$_4$	347.8	2.813/0°
30	— tetrachloride	SiCl$_4$	169.9	1.475
31	— tetrafluoride	SiF$_4$	104.1	
32	— tetrahydride	SiH$_4$	32.1	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
IV.		1 (100°)				1
1. Y.	v.s.s.		i. alc.			2
IV. C.	42.4 (10°)			W.H.		3
IV. Y.	s. d		s. alc.	50	100	4
III. W.	m.	s.		58	260	5
C. cryst.	v.s.	v.s.		d.		6
Gr.	i.	i.	i. CS_2, s.H_2SO_4	217	690	7
V., R.Bl.	i.	i.	CS_2, 1 : 1000	220		8
R.	i.	i.	CS_2, 1 : 1000	100—250		9
W. cryst	s.	s.			subl. 260	10
P.	d.		alc. d.	liq.	d. 225	11
Y.Br.	d.			liq.	d. 145	12
	d.			60—70		13
Y.	i.	i.	s. ether, CS_2	118—119		14
Am. Y.	i.	i.	i. alc., s. CS_2	expl. 200		15
W.	d.			10	179.5	16
Needles	s.		ac. d.	d. 100		17
Br.	d.		s. HCl, CS_2	75	d.	18
W.	d.		s. $POCl_3$	subl.	diss. 200	19
Gr.	d.			75—80		20
Am.&cryst	i.	i.	i. alc.	1780		21
Am. W.	freshly pptd.insol.		s. alk.			22
C.	d.				115—117	23
C.	d.		m. CS_2	-1.3	34	24
R.	d.			liq.	220	25
III. Bl., Am. Br.	i.	i	s. $HF+HNO_3$	1420±15		26
IV. plates	i.	i	i. ac.			27
W. needles	d.		d.	subl.		28
C.	d.			-12	153.4	29
C.	d.			-89	57.5	30
	d.			-102	-107	31
	i.			-200	-11/50atm.	32

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Silicon tetra-iodide	SiI_4	535.8	
2 — tribromide	Si_2Br_6	535.7	
3 — trichloride	Si_2Cl_6	269.0	1.58/0°
4 — tri-iodide	Si_2I_6	817.7	
5 Silico-oxalic acid	$Si_2O_2(OH)_2$	122.2	
6 Silver	Ag	107.88	10.47
7 — arsenate	Ag_3AsO_4	462.60	
8 — arsenite	Ag_3AsO_3	446.60	
9 — bromate	$AgBrO_3$	235.80	5.196/16°
10 — bromide	$AgBr$	187.80	6.47/25°
11 — carbonate	Ag_2CO_3	275.76	6.077
12 — chlorate	$AgClO_3$	191.34	4.43
13 — chloride	$AgCl$	143.34	5.501 ppd.; D :5.7/1735°
14 — chromate	Ag_2CrO_4	331.8	5.625
15 — cyanide	$AgCN$	133.90	3.99
16 — dichromate	$Ag_2Cr_2O_7$	431.8	4.669
17 — fluoride	$AgF+H_2O$	144.90	
18 — iodate	$AgIO_3$	282.80	5.402/17°
19 — iodide	AgI	234.80	5.67/14°
20 — nitrate	$AgNO_3$	169.89	4.35/19°
21 — nitride	AgN_3	149.91	
22 — nitrite	$AgNO_2$	153.89	
23 — oxide	Ag_2O	231.76	7.52
24 — peroxide	Ag_2O_2	247.76	7.4
25 — phosphate	Ag_3PO_4	418.68	7.32
26 — —, pyro	$Ag_4P_2O_7$	605.60	5.306/7.5°
27 — sulphate	Ag_2SO_4	311.82	5.41
28 — sulphide	Ag_2S	247.82	7.24 nat.

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
I. C.	i.	i	s. CS_2	120.5	290	1
IV. W.	d.				240	2
W.	d.			-1	146	3
III. C.	d.		s. CS_2	250 in vac.		4
Am. W.	i.		d.			5
I. W.	i.	i	s. HNO_3	960.5	W.H.	6
R.	i.		s. NH_4OH			7
Y.	i.		s. HNO_3, NH_4OH	d.		8
II.	i.	i	s.s. HNO_3 s. NH_4OH			9
I. Y.	i.	i	s.conc.$NH_4O]I$ s. conc. HBr	427	d. 700	10
Y. pdr.			s. ac.	loses CO_2 at 200		11
II. W.	10			230	d. 270	12
I. W.	i.	i	s. NH_4OH, KCN, $Na_2S_2O_3$	460		13
R. cryst.	0.0028 (18°)		s. ac., NH_4OH, KCN			14
W. cryst.	i.	i	s. NH_4OH, KCN	m. and d.		15
VI. R.		d.				16
II. C.	deliq.	v.s.		435		17
W. needles	s.s.	s.s.	s. NH_4OH, HNO_3	d.		18
III. G.	i.		v.s.s. NH_4OH s. conc. KI	540		19
IV.	190	1110	alc. h. 1 : 4	218	d. R.H.	20
W.	i.		s. NH_4OH	expl.		21
IIIa, W.	s.s.	s.	s. NH_4OH	d. 150	d. R.H.	22
Bl.	0.333		s. HNO_3	d. 250		23
I. Bl.	i.		s. HNO_3, NH_4OH	d. 110		24
Y.	i.		s. alk., ac.	R.H.		25
W.	i.			585		26
IV.	0.5	1.45	v.s. NH_4OH	825		27
I., Gr.Bl.	i.		s. NH_4OH, HNO_3	676	d.	28

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Silver sulphite	Ag_2SO_3	295.82	
2	— thiocyanate	$AgCNS$	165.96	
3	— thiosulphate	$Ag_2S_2O_3$	327.90	
4	Sodamide	$NaNH_2$	39.03	
5	Sodium	Na	23.00	0.732/15°
6	— aluminate	$Na_2Al_2O_4$	164.0	
7	— aluminium chloride	$2NaCl, Al_2Cl_6$	383.7	
8	— ammonium phosphate	$NH_4NaHPO_4+4H_2O$	209.15	1.55
9	— antimonate	$2NaSbO_3+7H_2O$	508.5	
10	— arsenate	$Na_3AsO_4+12H_2O$	324.06	1.7593
11	— bicarbonate	$NaHCO_3$	84.01	2.22/16°
12	— bisulphate	$NaHSO_4+H_2O$	138.09	an. 1.8
13	— bisulphite	$NaHSO_3$	104.07	1.48
14	— borate	$Na_2B_4O_7+10H_2O$	381.8	1.7156/17°
15	— bromate	$NaBrO_3$	150.92	3.339/17.5°
16	— bromide	$NaBr(+2H_2O)$	102.92	3.08
17	— carbonate	$Na_2CO_3+10H_2O$	286.16	1.45
18	— —, an.	Na_2CO_3	106.00	2.5
19	— chlorate	$NaClO_3$	106.46	2.29
20	— chloride	$NaCl$	58.46	2.174/20°
21	— chromate	$Na_2CrO_4+10H_2O$	342.2	2.71/16°
22	— cyanide	$NaCN$	49.01	
23	— dichromate	$Na_2Cr_2O_7+2H_2O$	298.0	2.52/16°
24	— dihydrogen phosphate	$NaH_2PO_4+H_2O$	138.08	2.04
25	— ferricyanide	$2Na_3Fe(CN)_6+H_2O$	579.88	
26	— ferrocyanide	$Na_4Fe(CN)_6+12H_2O$	520.18	
27	— fluoride	NaF	42.0	2.766
28	— hydrosulphite	$Na_2S_2O_4(+2H_2O)$	174.12	
29	— hydride	NaH	24.01	0.92
30	— hydrogen arsenate	$Na_2HAsO_4+12H_2O$	402.21	1.67
31	— — arsenite	Na_2HAsO_3	169.97	1.87
32	— — phosphate	$Na_2HPO_4+12H_2O$	358.29	1.525/16°
33	— — phosphite	$Na_2HPO_3+5H_2O$	216.13	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C	
W.	i.		s. NH_4OH	d. 400		1
W.	i.	i	s. NH_4OH	d.		2
W.	s.s.		s. NH_4OH	d.		3
Cryst.	s.	d.		155	subl. 400	4
II. (?), W.	d.		d.	97.5	742	5
	s.	s.				6
C.	deliq.			185	R.H.	7
V. C.	16	100	i. alc.	d.		8
W.				2 aq 200 an. R.H.		9
	26.7 (17°)					10
V.	8	d.	i. alc.	d. 270		11
V., an. VI.	v.s.	v.s.	i. alc.	300		12
	s.	s.	i. alc.			13
V.+5 aq. I	6.2	201.4	i. alc.	R.H.		14
I.	s.	s.		384		15
V., an. I.	87	120	s.s alc.	733—765		16
V.	92.5	539.6	i. alc.	5 aq 12.5, 34	106	17
W. pdr.	16.5	45	i. alc.	853	d.	18
I.	94.2	232.6	s. alc.	248	d.	19
I.	35	39.5	i. alc.	792	W.H.	20
V. Y.	s.	s.		23		21
	s.	v.s.	s.s. alc.			22
VI. R.	109	163		aq110 ; 320	d. 400	23
IV.	s.		i. alc.	d. 200		24
R. prism.	19.0	80.0				25
V. Y.	s.	s.				26
I. C.	4.78		s.s. alc.	902		27
C. cryst.	v.s.	d.	i. alc.	d. R.H.		28
C. cryst.	d.		s. fused Na	d.		29
	28	v.s.	1.8 alc.			30
	v.s.	v.s.				31
V.	aq. free 5.8	98.8	i. alc.	38	3 aq 160	32
IIIa	s.	s.		53		33

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Sodium hydrogen sulphide	$NaHS + 2 H_2O$	92.10	
2 — hydroxide	$NaOH$	40.01	2.13
3 — hypochlorite	$NaClO$	74.46	
4 — hypophosphite	$NaH_2PO_2 + H_2O$	106.08	
5 — iodide	$NaI + 2 H_2O$	185.95	2.448 ; an, 3.65/18°
6 — iodate	$NaIO_3 (+5H_2O)$	197.92	4.277
7 — manganate	$Na_2MnO_4 + 10 H_2O$	345.09	
8 — metastannate	$Na_2Sn_5O_{11} + 4 H_2O$	887.6	
9 — molybdate	$Na_2MoO_4 + 2 H_2O$	242.0	
10 — monoxide	Na_2O	62.00	2.805
11 — nitrate	$NaNO_3$	85.01	2.27/20°
12 — nitrite	$NaNO_2$	69.01	
13 — nitroprusside	$Na_2Fe(CN)_5NO + 2 H_2O$	297.96	
14 — perborate	$NaBO_3 + 4 H_2O$	154.0	
15 — perchlorate	$NaClO_4$	122.46	
16 — permanganate	$NaMnO_4$	141.93	
17 — peroxide	Na_2O_2	78.00	2.8
18 — pentasulphide	$Na_2S_5 (+8 H_2O)$	206.30	
19 — phosphate, ortho	$Na_3PO_4 + 12 H_2O$	380.28	1.62
20 — —, meta	$NaPO_3$	102.04	2.476
21 — —, pyro	$Na_4P_2O_7 + 10 H_2O$	446.24	1.8
22 — phosphide	Na_3P	100.04	
23 — platinichloride	$Na_2PtCl_6 + 6 H_2O$	562.1	2.499
24 — pyroantimonate	$Na_2H_2Sb_2O_7 + 6 H_2O$	508.5	
25 — silicate	Na_2SiO_3	122.1	
26 — silicofluoride	Na_2SiF_6	188.3	2.75
2 — stannate	$Na_2SnO_3 + 3 H_2O$	266.8	
28 — sulphate	$Na_2SO_4 + 10 H_2O$	322.22	1.492/20°
29 — suphide	$Na_2S + 9 H_2O$	240.20	2.471
30 — suphite	$Na_2SO_3 + 7 H_2O$	252.17	1.561
31 — tetrasilicate	$Na_2Si_4O_9$	302.4	
32 — thioantimonate	$Na_3SbS_4 + 9 H_2O$	479.58	1.806
33 — thioarsenate	$2Na_3AsS_4 + 15 H_2O$	814.74	
34 — thiosulphate	$Na_2S_2O_3 + 5 H_2O$	248.20	1.736/10°

| Crystalline form and colour | Solubility in | | | M.P. °C. | B.P. °C. | |
	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies			
Cryst.	deliq.		s. alc.	d.		1
Am. W.	105	335	s. alc.	318	W.H.	2
Needles	s.	d.		d.		3
	deliq.	s.		aq in vac.		4
I.	174	300	s. alc.	abt. 650		5
	6.8	33.9	i.alc., s. acetic	d.		6
V. G.	v.s.	d.		d.		7
Cryst. pdr.	s.s.		i. alc.			8
IIIa	s.	s.				9
	d.		d. alc.	R.H.	subl.	10
IIIa	84	180	93% alc. 0.93	313		11
IV.	83	v.s.	i. alc.	213		12
R. prism.	40					13
V. prism.	2.5 (20°)	d.	with H_2SO_4 : H_2O_2			14
IIIa. C.	deliq.	v.s.		d.		15
R.	deliq.	v.s.		d.		16
Y.W.	s. d.		with H_2SO_4 : H_2O_2	d.		17
	s.	s.	s.s. alc.	d.		18
III	20	s.	—	73,11aq100		19
W.	fused i.			617		20
V.	8.8	93.1	i. alc.		76.7	21
R.	yields PH_3			d.		22
VI. R.	v.s.	v.s.	s. alc.	an. 100		23
	v.s.s.	v.s.s.	v.s.s. alc.			24
V.+5 aq.	s.	s.	i. alc.	1007		25
III. C.	0.6	2.5				26
III.	s.	s.s.				27
V., an. IV.	(+10 aq.) 29.9	113 (33°)	i alc.	7 aq 150 ; 880		28
II.	s.	s.	s. alc.	d.		29
V.	(+7 aq.) 46	66	i alc.	7 aq 150	d.	30
Am. O	s.	s.	i. alc.			31
I. Y.	33		i. alc.	d.		32
	s.					33
V.	65	109 (45°)	i. alc.	32—48	d. 220	34

	Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Sodium tungstate	$Na_2WO_4 + 2H_2O$	330.0	3.3 ; an. 4.18
2	Stannic acid or Metastannic acid	H_2SnO_3 to H_4SnO_4		
3	Stannic bromide	$SnBr_4$	438.4	3.340/35°
4	— chloride	$SnCl_4$	260.5	2.27/20°
5	— fluoride	SnF_4	194.7	4.78/19°
6	— iodide	SnI_4	626.4	4.696/11°
7	— oxide	SnO_2	150.7	6.6—6.9
8	— sulphide	SnS_2	182.8	4.6
9	Stannous bromide	$SnBr_2$	278.5	5.117/17°
10	— chloride	$SnCl_2 + 2H_2O$	225.7	2.71
11	— iodide	SnI_2	372.5	
12	— oxide	SnO	134.7	6.3
13	— sulphide	SnS	150.8	4.973 cryst
14	Strontium	Sr	87.63	2.542
15	— bromate	$Sr(BrO_3)_2 + H_2O$	361.49	3.773
16	— bromide	$SrBr_2 (+6H_2O)$	247.47	4.2/24°
17	— carbonate	$SrCO_3$	147.63	
18	— chlorate	$Sr(ClO_3)_2$	254.55	3.62
19	— chloride	$SrCl_2 + 6H_2O$	266.65	1.964 ; an. 3.05
20	— dithionate	$SrS_2O_6 + 4H_2O$	319.81	2.373
21	— fluoride	SrF_2	125.63	4.2—4.24
22	— hydroxide	$Sr(OH)_2 + 8H_2O$	265.78	1.396
23	— iodide	SrI_2	341.47	4.415
24	— nitrate	$Sr(NO_3)_2$	211.65	2.962/4°
25	— oxide	SrO	103.63	3.6
26	— peroxide	$SrO_2 + 8H_2O$	263.76	

Crystalline form and colour	Solubility* in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
C. plates	(+2 aq.) 55.5	125		an. 100		1
W.	i.	stannic meta stannic	s. HNO₃, alk. i HNO₃, s. alk., HCl	d.		2
W.	v.s.	d.		33	201	3
	s., d. excess aq.		s. CS₂	liq. −33	114.1	4
W. cryst.	deliq.	d.		subl.	705	5
R. oct.	d.		s. org. sol.	143	341	6
II., Am. W	i.		s. alk., i. ac.	1130		7
Y. III.	i.		s. alk.	d. R.H.		8
Y.	s.			215.5	619	9
VI.	275	d. with excess aq.	s. alc.	40, an. 249	620	10
Y.R. ndl.	s.s		s. HCl	316		11
I. Bl.	i.		s NH₄Cl	d. R.H.		12
Gr.Bl.	i.		s. HCl	R.H.		13
Y.	d.	—		<800	abt. 1000	14
	(+aq.) 33			aq 100	d. 240	15
C. needles	99 (20°)	250 (110°)		498—630		16
IV.	0.0056		s. CO₂ soln.	d. 1160	d R.H.	17
IV.	s.	s.	s.s.	290 and d.		18
III.	51.0	101.9	alc. 4.6	an. 854	4 aq 60 6 aq 100	19
III. plates	(+ aq.) 20	60	i. alc.	4 aq 78		20
I.	s.	s.				21
II.	(+8 aq.)1.9	41		8 aq 100		22
Plates	179 (20°)	370		402		23
I.; +4 aq. V.	62.8	101.1	v.s.s. alc.	d. 645		24
IV.	35 (0°)	s.	s. ac.	3000		25
W. cryst.	s.s.			d. R.H.	8 aq <60	26

	Name	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1	Strontium silicofluoride	$SrSiF_6 + 2 H_2O$	265.8	
2	— sulphate	$SrSO_4$	183.69	3.707 ppd.
3	— sulphide	SrS	119.69	3.7
4	— thiosulphate	$SrS_2O_3 + 5 H_2O$	289.83	2.156
5	Sulphamide	$SO_2(NH_2)_2$	96.11	
6	Sulphur, oct.	S	32.06	2.0748
7	—, prism.	S	32.06	1.957
8	—, amorph.	S	32.06	2.046 ; D : 2.23/850°
9	— dichloride	SCl_2	102.98	1.62
10	— dioxide	SO_2	64.06	liq. 1.434/0°
11	— hexafluoride	SF_6	146.06	
12	— hexa-iodide	SI_6	793.58	
13	Sulphuric acid, conc.	$H_2SO_4 (98.5\%)$		1.854
14	— —, vitriol	$H_2SO_4 (92\%)$		1.835/20°
15	— —, hydrate	$H_2SO_4 + H_2O$	116.10	1.788/17°
16	— —, hydrate	$H_2SO_4 + 2 H_2O$	134.11	1.665/0°
17	— —, "monohydrate"	H_2SO_4	98.08	1.834/18°
18	— —, pyro	$H_2S_2O_7$	178.14	1.89
19	Sulphur monochloride	S_2Cl_2	135.04	1.706/0°
20	— monoxytetrachloride	S_2OCl_4	221.96	1.656 D. 3.86/100°
21	— trioxide	SO_3	80.06	1.9546/13°
22	— —, solid	$(SO_3)_2$	160.12	1.040
23	— trioxytetrachloride	$S_2O_3Cl_4$	253.96	
24	Sulphuryl chloride	SO_2Cl_2	134.98	1.66/20°
25	Tantalum	Ta	181.5	16.5
26	— chloride	$TaCl_5$	358.8	
27	— oxide	Ta_2O_5	443.0	7.5 am.
28	Tetraphosphorus monoselenide	P_4Se_2	282.6	
29	— trisulphide	P_4S_3	220.34	
30	Telluric acid	$H_2TeO_4 + 2 H_2O$	229.5	

Crystalline form and colour	Solubility* in			M.P. °C.	B.P. °C.	
	100 parts water at 15°C (60°F)	100 parts water at 100°C (212°F)	Alcohol, acids or alkalies			
	v.s.	v.s.				1
IV.	0.145	0.01	s.s. ac.	d. W.H.		2
I.	d.		s. alo.			3
V.	16.6 (10°)	50	i. alc.	4 aq 100		4
IV. plates	s.		s. alc.	91.5	d. 250	5
IV. Y.	i.	i	s.s. alc., s. CS$_2$	114—115	444.6	6
V.	i.	i	CS$_2$, 73 : 100	114.4	444.6	7
	i.	i	i. CS$_2$	>120		8
	d.			liq.	d. 70	9
Br.	688 vol. at 0°	170 vol. at 40°	alc. 328 vol. at 0°	-72.7	-10.1	10
W.	i.	s.s.	s.s. alc.	-55	-50	11
Gr.Bl.cryst		d.	s. CS$_2$			12
	m.	m.	d. alc.	liq.	315—317	13
	m.	m.	d. alc.	liq.		14
	m.	m.	d. alc.	+8	210—338	15
	m.	m.	d. alc.	-70	170—190	16
	m.	m.	d. alc.	10.5	d. 40	17
Prism.	d.		d.	35		18
Y.	d.		s. CS$_2$	liq.	138	19
R.	d.			liq.	100	20
W. needles	d.		d.	14.8	46.2	21
W. cryst	d.			35		22
W. needles	d.			57	subl.	23
	d.		s. acetic	liq.	70.5	24
Gr.				2900		25
Y.	d.		s. alc.	221	241.6	26
Am. W.	i.		s. KHSO$_4$			27
	i.	i.	s. alc., ether, CS$_2$	-12		28
IV. Y.	i.	d.	s. CS$_2$, PCl$_3$, KHS soln.	166	>300	29
III.	s.		HCl d.	d. R.H.	2 aq 160	30

	Name	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1	Tellurium	Te	127.5	D:9/1400°; 6.26
2	— dioxide	TeO_2	159.5	5.9/0°
3	— hydride	H_2Te	129.5	
4	— trioxide	TeO_3	175.5	5.07/15°
5	Tellurous acid	H_2TeO_3	177.5	
6	Thallic bromide	$TlBr_3$	443.8	
7	— chloride	$TlCl_3 + H_2O$	328.4	
8	— hydroxide	$TlO(OH)$	237.0	
9	— nitrate	$Tl(NO_3)_3 + 3 H_2O$	444.1	
10	— sulphate	$Tl_2(SO_4)_3 + 7 H_2O$	822.3	
11	— sulphide	Tl_2S_3	504.2	
12	Thallium	Tl	204.0	11.862
13	— monoxide	Tl_2O	424.0	
14	— trioxide	Tl_2O_3	456.0	5.56/0°
15	Thallous bromide	$TlBr$	283.9	7.54/22°
16	— carbonate	Tl_2CO_3	468.0	7.164
17	— chloride	$TlCl$	239.5	7.02
18	— fluoride	TlF	223.0	
19	— hydroxide	$TlOH(+H_2O)$	221.0	
20	— iodide	TlI	330.9	7.07
21	— nitrate	$TlNO_3$	266.0	5.55
22	— phosphate	Tl_3PO_4	707.0	6.89/10°
23	— sulphate	Tl_2SO_4	504.1	6.765
24	— sulphide	Tl_2S	440.1	8
25	Thionyl chloride	$SOCl_2$	118.98	1.676
26	Thiophosphoric acid	$PS(OH)_3$	114.12	
27	Thiophosphoryl bromide	$PSBr_3$	302.86	2.85/17°
28	— chloride	$PSCl_3$	169.49	D:5.878/298°; 1.6816/0°
29	— triamide	$PS(NH_2)_3$	111.18	1.7/13°
30	Thiopyrophosphoryl bromide	$P_2S_3Br_4$	477.94	2.262/17°
31	Thorium chloride	$ThCl_4$	374.2	4.59
32	— nitrate	$Th(NO_3)_4$	480.4	

Crystalline form and colour	Solubility*in 100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
Gr.W.	i.	i	s. H_2SO_4	450	1390	1
I. Y.	i.			dark R.H.	<700	2
	s.		s. alc.	−54		3
Y. cryst.	i.				d. R.H	4
W.	s.s.	d.		d. 40		5
Y. needles	s.	s.	s. alc.	d.		6
	v.s.	d.		aq 60	d. 100	7
Y. cryst.	s.		s. alc.	d. 100		8
C. cryst.	deliq.	d.		d. 100		9
C. cryst.	d			6 aq 220	d.	10
Am. Bl.	i.	i	s.h. H_2SO_4		d.	11
Am.	i.		S. HNO_3	302	1290	12
Bl.	s.		s. ac.	300		13
III. Bl.	i.	i	s. HCl			14
W.				460		15
V.	5.2	22.4	i.	d. 272		16
I. W	0.265	1.427	i. HCl, alc.	451	719—731	17
Oct.	80	<80				18
	s.			d. 100		19
I. Y.	0.00625	0.125	s. HNO_3	439	800—806	20
IV.	10.6	508/108°	i. alc.	205		21
W.	0.5	0.75	i. alc.			22
IV.	4.8	19.3		632	d.	23
Br.	i.	i	s. ac.	d.		24
	d.			liq.	78.8	25
	s.	d.	s. alc.			26
Y.	d.		s. CS_2	38	d.	27
C.	d.			liq.	126	28
W.	s.s.	d.	s. alc.	d. 200		29
Y.	d.			liq.	d.	30
W. plates	deliq.			820	subl.	31
Plates	deliq.		s. alc.			32

	Name.	Formula.	Formula Weight.	Density. Water=1 D:Air=1
1	Thorium oxide	ThO_2	264.4	9.87/15° cryst
2	Tin	Sn	118.7	7.29
3	Titanium	Ti	48.1	3.45, fus. 4.9
4	— dioxide	TiO_2	80.1	3.7—4.2
5	— tetrachloride	$TiCl_4$	189.9	1.76/0°
6	Triphosphonitrile chloride	$P_3N_3Cl_6$	347.91	1.98
7	Tungsten	W	184.0	19.13
8	— dioxide	WO_2	216.0	12.1
9	— hexachloride	WCl_6	396.8	D : 13.3/350°
10	— pentachloride	WCl_5	361.3	3.52
11	— trioxide	WO_3	232.0	7.16 am.
12	— trisulphide	WS_3	280.2	
13	Tungstic acid hydrate	$H_2WO_4 + H_2O$	268.0	
14	Uranium	U	238.2	18.68
15	— oxide	UO_2	270.2	10.9
16	— sulphate	$U(SO_4)_2 + 8H_2O$	574.5	
17	— tetrachloride	UCl_4	380.0	
18	Uranyl chloride	UO_2Cl_2	341.1	
19	— nitrate	$UO_2(NO_3)_2 + 6H_2O$	502.3	2.81
20	— phosphate	$UO_2(HPO_4) + 4H_2O$	438.3	
21	— sulphate	$2UO_2SO_4 + 7H_2O$	859.6	
22	Vanadic acid, meta	HVO_3	100.0	
23	Vanadium	V	51.0	5.5
24	— dichloride	VCl_2	121.9	3.23
25	— monosulphide	V_2S_2	166.1	4.2—4.4
26	— monoxide	V_2O_2	134.0	3.64
27	— pentoxide	V_2O_5	182.0	3.5/20°
28	— sesquioxide	V_2O_3	150.0	4.72/16°
29	— sesquisulphide	V_2S_3	198.2	3.7, 4.0
30	— tetrachloride	VCl_4	192.8	1.8585
31	— trichloride	VCl_3	157.4	3/18°

Crystalline form and colour	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies	M.P. °C.	B.P. °C.	
I., Am. W.	i.		s. conc. H_2SO_4	infusible		1
W. cryst.	i.		s.h. ac.	231.9	W.H.	2
Gr.		d.	s. HCl	1800—1850		3
II. IV.	i.			1500		4
	s.	d.		- 25	136	5
	i. d.		s. alc., ether	114	250	6
II. Gr. W	i.		s. HNO_3	3000±100		7
Br.	i.		s.s.ac.,s.KOH			8
Viol.Bl.	d. 60°		s. CS_2	275	346.7	9
Bl. cryst.	deliq.		—	248	275.6	10
IV. Y.	i.		s. alk.	R.H.		11
Bl.	s.s.	s.	s. alk.			12
W.	s.s.		s. alk.	at 100: $H_2W_2O_7$		13
G., W.	i.	i	s. ac.	W.H.		14
I., G., Bl.	i.	i	i. conc. H_2SO_4	oxid.		15
G. cryst.	s.		i. alc.	d.		16
I. G.	v.s.	s.	s. alc.	gas		17
R., Br. Bl.	320 (18°)	s.	s. alc., ether	fusible	d.	18
Y. cryst	(+6aq.)200	v.s.	v.s. alc.	59.5	118	19
IV. Y.	i.	i	i. acetic acid	aq 60		20
Y.	v.s.	v.s.	s. H_2SO_4	an. 300		21
Y. Br.	s.	s.				22
Cryst.			s. HNO_3, conc. H_2SO_4	1730		23
III. Y.	s.	s.	s. alc.			24
Bl.			i. HCl, s. h. H_2SO_4			25
Gr. pdr.	i.	i	s. ac.			26
IV. R.	1 :1000		s. ac., alk.	658		27
Bl.	s.	s.	s. HNO_3,i.alk.	infusible		28
Bl. plates, Gr. pdr.			s.s. conc. ac. s. am. sulph.			29
R.Br.	s.			- 18 liq.	154	30
R. plates	deliq.		s. alc.			31

Name.	Formula.	Formula Weight.	Density. Water=1 D : Air=1
1 Vanadyl sulphate	$(VO)_2(SO_4)_3$	422.2	
2 — trichloride	$VOCl_3$	173.4	1.841
3 Water	H_2O	18.016	0.9568 100°/4°
			ice 0.91674 0°/0°
4 Yttrium oxide	Y_2O_3	225.4	5.046
5 — nitrate	$Y(NO_3)_3 + 6 H_2O$	382.8	
6 Zinc	Zn	65.37	6.86—7.21 D : 2.26/1400
7 — bromate	$Zn(BrO_3)_2 + 6 H_2O$	429.31	
8 — bromide	$ZnBr_2$	225.31	3.643
9 — carbonate	$ZnCO_3 + H_2O$	143.39	4.42
10 — chlorate	$Zn(ClO_3)_2 + 6 H_2O$	340.39	
11 — chloride	$ZnCl_2$	136.29	2.91/25°
12 — hydroxide	$Zn(OH)_2$	99.39	2.877
13 — iodide	ZnI_2	319.21	4.696
14 — nitrate	$Zn(NO_3)_2 + 6 H_2O$	297.49	
15 — oxide	ZnO	81.37	5.61
16 — phosphate	$Zn_3(PO_4)_2$	386.19	3.99/15°
17 — sulphate	$ZnSO_4 + 7 H_2O$	287.54	1.96 ; 3.4 an.
18 — sulphide	ZnS	97.43	4.0
19 Zirconium chloride	$ZrCl_4$	232.4	
20 — fluoride	ZrF_4	166.6	4.433
21 — oxide	ZrO_2	122.6	5.1—5.7

| Crystalline form and colour | Solubility in | | | M.P. °C. | B.P. °C. | |
	100 parts water at 15°C(60°F)	100 parts water at 100°C(212°F)	Alcohol, acids or alkalies			
B.	deliq.					1
Y.	d.				-15 liq. 126.7	2
III.			m. alc.	0	100	3
W. cryst.	i.		s. mineral ac.			4
C. plates	deliq.		s. alc., ether	17, -6 aq		5
III., W.	i.	slight d	s. ac.	419.4	930	6
I.	s.	s.		100	6 aq 200	7
	s.	s.	s. alc., ether	390	695	8
IIIa, an.	i.	i	i. alc.	d. 300		9
I. W.	s.	s.	s. alc.	60		10
W. cryst.	330 (10°)	v.s.	alc. 1 : 1	262	730	11
IV ; +aq.I.	i.	i	s. alk., ac.	d.		12
	deliq.	v.s.	s. alc.	d.		13
II.	deliq.	v.s.	s. alc.	36.4	6 aq 105	14
III. W.	1 : 100000		s. alc.	W.H.		15
Prism.		655		R.H.		16
IV.	(+7aq.)135		i.	6 aq 100	aq R.H.	17
1. W.	1.	i	s. ac.	1049		18
W.	v.s.	s. d.	s. alc.			19
III. C.	i.		i. ac.	W.H		20
II., V	i.		s. conc. H_2SO			21

Nomenclature of Organic Compounds (Richter).

In numbering positions in the case of substitution derivatives of phenol, aniline, toluene, etc., the characteristic radical of each of these substances is regarded as in position 1.
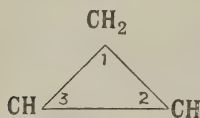
CH_2 · 1 · CH 3 · 2 CH
Cyclo-Propene.
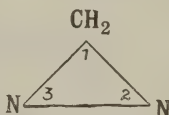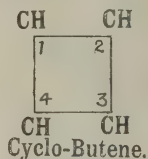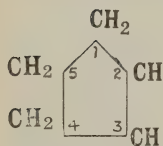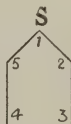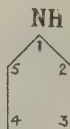
CH_2 · 1 · N 3 · 2 N
Azimethylene.

CH 1 · CH 2 · CH 4 · CH 3
Cyclo-Butene.

CH_2 1 · CH_2 5 · 2 CH · CH_2 4 · 3 CH
Cyclo-Pentene.

O 1 · 5 · 2 · 4 · 3
Furan.

S 1 · 5 · 2 · 4 · 3
Thiofuran.

NH 1 · 5 · 2 · 4 · 3
Azole.

NH 1 · 5 · 2 N · 4 · 3
1. 2. Diazole.

O 1 · 5 · 2 · 4 · 3 N
Oxazole.

S 1 · 5 · 2 · 4 · 3 N
Thiazole.

O 1 · 5 · 2 N · 4 · 3 N
1. 2. 3. Oxdiazole.

CH 5 · O 1 · 2 O · N 4 · 3 N
1. 2. 3. 4. Dioxdiazole.

1 · 6 · 2 · 5 · 3 · 4
Benzene.

N 1 · 6 · 2 · 5 · 3 · 4
Azine.

N 1 · 6 · 2 N · 5 · 3 · 4
1. 2. Diazine.

N
1
6 2 N
5 3
      N

1.2.3. Triazole.

O
1
6 2 N
5 3
      4
      CH₂

1.2. Oxazine (4)

O
1
6 2 CH₂
5 3
      4

1.2. Pyran.

O
1
6 2 CO
5 3
      4

1.2. Pyrone.

CH₂   CH₂
O   6 2   O
   5 3
      4
      CH₂

1.2.3. Trioxine.

CH₂
7 1
6   2
5   3
4

Indene.

O
6 1
5   2
4
3

Benzfuran.

S
6 1
5   2
4
3

Benzthiofuran.

NH
6 7 1
5   2
4   5

Benzazole.

NH
7 1
N 6 8 2
5   3 N
4
N
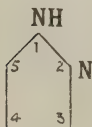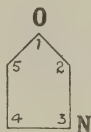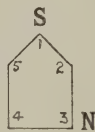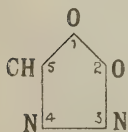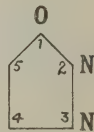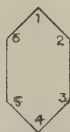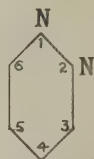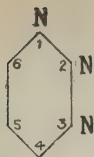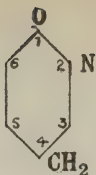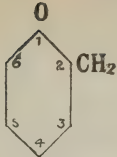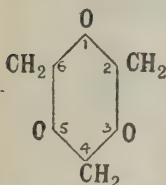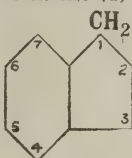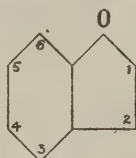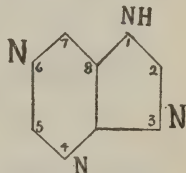
Purine.
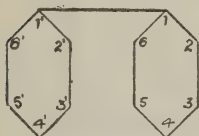
Diphenyl.   CH₂

Naphthalene.

1. Benzazine.

α-Naphthindene

CH₂
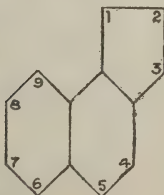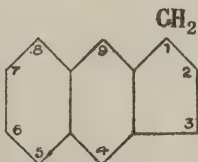
β-Naphthindene.

CH₂
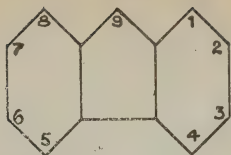
Fluorene.

NH

Carbazole.

Anthracene.

CH₂

O

Xanthene.

N

Anthrapyridine.

N

Acridine.

N
N

1. 2. Naphthdiazine.

N

CO
NH

Phenazone.
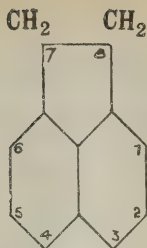
Acenaphthene.
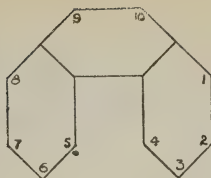
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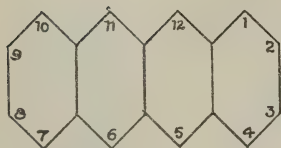
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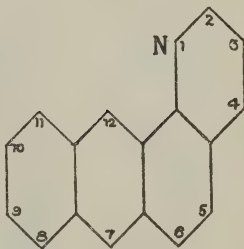
α-Anthraquinoline.
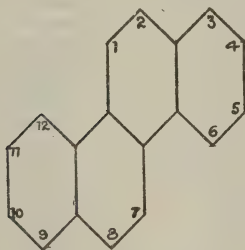
Chrysene.
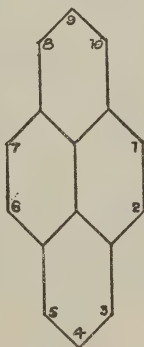
Pyrene.

GENERAL PROPERTIES OF

Salts and esters follow the corresponding organic acids. Most *iso*
are given in alphabetical order. For numbering of position

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Abiëtic acid	$C_{20}H_{30}O_2$	303.32	$C_{20}H_{30}O_2$
2	Acenaphthene	$C_{10}H_6:(CH_2.CH_2)$	154.14	$C_{12}H_{10}$
3	Acenaphthylene	$C_{10}H_6:(CH:CH)$	152.12	$C_{12}H_8$
4	Acetal	$CH_3.CH:(OC_2H_5)_2$	118.14	$C_6H_{14}O_2$
5	Acetaldehyde	$CH_3.CHO$	44.04	C_2H_4O
6	— ammonia	$CH_3.CHOH.NH_2$	61.08	C_2H_7ON
7	— cyanhydrin	$CH_3.CH(OH)CN$	71.06	C_3H_7ON
8	— phenyl hydrazone, α	$CH_3.CH:N.NH.C_6H_5$	134.14	$C_8H_{10}N_2$
9	— — —, β	,, ,,	134.14	,,
10	— semi-carbazone	$CH_3.CH:N.NH.CO.NH_2$	87.09	$C_3H_7ON_3$
11	Acetaldoxime	$CH_3.CH:NOH$	59.06	C_2H_5ON
12	Acetamide	$CH_3.CO.NH_2$	59.06	C_2H_5ON
13	— chloride	$CH_3.CCl_2.NH_2$	113.98	$C_2H_5NCl_2$
14	Acetamidine	$CH_3.C(NH)NH_2$	58.08	$C_2H_6N_2$
15	Acetamino phenol	$CH_3.CONH.C_6H_4.OH$	151.12	$C_8H_9O_2N$
16	Acetanilide	$C_6H_5.NH.COCH_3$	135.12	C_8H_9ON
17	Acetic acid	$CH_3.COOH$	60.04	$C_2H_4O_2$
18	Acetate, ammonium	CH_3COONH_4	77.08	$C_2H_7O_2N$
19	— calcium	$(CH_3COO)_2Ca.2H_2O$	194.17	$C_4H_{10}O_6Ca$
20	— cupric	$(CH_3COO)_2Cu.H_2O$	199.66	$C_4H_8O_5Cu$
21	— ferric	$(CH_3COO)_6Fe_2$	465.88	$C_{12}H_{18}O_{12}Fe_2$
22	— lead	$(CH_3COO)_2Pb$	443.34	$C_8H_{12}O_8Pb$
23	— — (sugar of lead)	$(CH_3COO)_2Pb.3H_2O$	379.32	$C_4H_{10}O_7Pb$
24	— — basic	$CH_3COO.PbO.PbOH$	506.44	$C_4H_9O_4Pb_2$
25	— potassium	CH_3COOK	98.13	$C_2H_3O_2K$
26	— sodium	$CH_3COONa.3H_2O$	136.08	$C_2H_9O_5Na$
27	— uranyl	$(CH_3COO)_2UO_2.3H_2O$	442.32	$C_4H_{12}O_9U$
28	— zinc	$(CH_3COO)_2Zn.3H_2O$	223.47	$C_4H_{12}O_7Zn$
29	— allyl	$CH_3COOC_3H_5$	100.09	$C_5H_8O_2$
30	— amyl	$CH_3COOC_5H_{11}$	130.15	$C_7H_{14}O_2$
31	— benzyl	$CH_3COOC_7H_7$	150.13	$C_9H_{10}O_2$
32	— bornyl, d	$CH_3.COOC_{10}H_{17}$	196.22	$C_{12}H_{20}O_2$
33	— ethyl	$CH_3COOC_2H_5$	88.08	$C_4H_8O_2$

ORGANIC COMPOUNDS.

compounds follow the corresponding *normal* compounds. Substituents in cyclic compounds, see " Notation of Organic Compounds."

Density $H_2O=1$	Water	Alcohol	Ether	M.P. °C.	B.P. °C.	
	i.	s.	s.s. acetic	161		1
1.03		c.s.s.		95	277.5	2
	i.	v.s.	v.s.	93	265—275 d.	3
0.821/22°	c. 1:18	v.s.	s.	liq.	104	4
0.778/16°	v.s.	s.	s.	− 120.7	20.8	5
	s.		s.s.	96—98	100	6
	v.s.	v.s.		182—184 d.		7
			1 :20 ligroin	98	236—237/20mm.	8
		s.	1 :6 ligroin	56	133—136/20mm.	9
	s.s.	s.s.		162		10
	m.	m.	m.	45	114—115	11
1.159	v.s.	v.s.	v.s.	83	215.5/749mm.	12
	d.				88—89/762mm.	13
	d.		s. ac.			14
1.293/21°	h.v.s.s.	c.v.s.		166—167		15
1.21/4°	1 : 189	s.	s.	113 (corr.)	283	16
1.05704/15°	m.	s.	s.	16.68	117.88	17
1.073	v.s.			120		18
	s.		s.s.	100 an.		19
1.882	h. 1 : 5	1 : 14		100 an.	d. 240	20
	s.	s.				21
				175		22
2.496	c. 1 : 1.5	s.		75, an. 280		23
	1 : 18	s.s.				24
	del. 1 : 0.5	c. 1 : 3	i.	292	d. R.H.	25
		s.s.		58, an. 319		26
1.42	1 : 2.8	s.		aq. 100, 275		27
1.735	v.s.			235—237	3 aq. 100	28
0.9376/0°		s.		liq.	105	29
0.879/20°	i.	s.	s.	liq.	148	30
1.057/16.5°				liq.	215.3/756mm.	31
				29	221	32
0.9048/0°	1 : 17/17.5°	m.	m.	− 82.8	77.2	33

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Acetate, ethylene	$(CH_3COO)_2:C_2H_4$	146.11	$C_6H_{10}O_4$
2	— hexyl	$CH_3COOC_6H_{13}$	144.17	$C_8H_{16}O_2$
3	— methyl	CH_3COOCH_3	74.06	$C_3H_6O_2$
4	— methylene	$(CH_3COO)_2:CH_2$	132.09	$C_5H_8O_4$
5	— naphthyl, a	$CH_3COOC_{10}H_7$	186.14	$C_{12}H_{10}O_2$
6	—— β	,, ,,	186.14	,,
7	— phenyl	$CH_3COOC_6H_5$	136.10	$C_8H_8O_2$
8	Acetic anhydride	$(CH_3CO)_2:O$	102.07	$C_4H_6O_3$
9	Acetin, mono	$(OH)_2:O_3H_7.O.COCH_3$	134.11	$C_5H_{10}O_4$
10	Acetnaphthalide, a	$C_{10}H_7.NH.COCH_3$	185.16	$C_{12}H_{11}ON$
11	— β	,, ,,	185.16	,,
12	Aceto-acetanilide	$CH_3CO.CH_2CO.NH.C_6H_5$	177.15	$C_{10}H_{11}O_2N$
13	— acetic acid	$CH_3CO.CH_2COOH$	102.07	$C_4H_6O_3$
14	———, ethyl ester	$CH_3CO.CH_2COOC_2H_5$	130.11	$C_6H_{10}O_3$
15	— benzidine	$NH_2.C_6H_4.C_6H_4.NH.COCH_3$	226.20	$C_{14}H_{14}ON_2$
16	— diphenylamine	$(C_6H_5)_2:N.COCH_3$	211.18	$C_{14}H_{13}ON$
17	— toluide, o	$C_7H_7.NH.COCH_3$	149.14	$C_9H_{11}ON$
18	—— m	,, ,,	149.14	,,
19	—— p	,, ,,	149.14	,,
20	Acetol	$CH_3CO.CH_2OH$	74.06	$C_3H_6O_2$
21	Aceton acid, see	Hydroxy butyric acid		
22	Acetone	CH_3COCH_3	58.06	C_3H_6O
23	— chloride	$CH_3OCl.CH_3$	100.98	C_3H_7OCl
24	— cyanhydrin	$(CH_3)_2.C(OH)CN$	85.09	C_4H_7ON
25	— diacetic acid	$CO:(CH_2.CH_2COOH)_2$	174.12	$C_7H_{10}O_5$
26	— dicarboxylic acid	$CO:(CH_2COOH)_2$	146.07	$C_5H_6O_5$
27	— phenylhydrazone	$(CH_3)_2:C:N.NHC_6H_5$	148.15	$C_9H_{12}N_2$
28	— semicarbazone	$(CH_3)_2:C:N.NH.CONH_2$	115.12	$C_4H_9ON_3$
29	Acetonitrile	CH_3CN	41.04	C_2H_3N
30	Acetonyl acetone	$CH_3CO.CO.CH_2CH_2CH_3$	116.13	$C_6H_{12}O_2$
31	Acetonylurea	$C_5H_8N_2O_2$	123.07	$C_5H_8O_2N_2$
32	Acetophenine	$C_{24}H_{19}N_3$	321.28	$C_{24}H_{19}N_3$
33	Acetophenone	$C_6H_5.COCH_3$	120.10	C_8H_8O
34	— acetone	$C_6H_5.COCH_2.CH_2COCH_3$	176.15	$C_{11}H_{12}O_2$
35	— carboxylic acid, see	Acetyl benzoic acid		
36	Acetoxime	$(CH_3)_2:C:NOH$	73.08	C_3H_7ON
37	Aceturic acid, see	Acetyl glycine		
38	Acetyl acetone	$CH_3CO.CH_2COCH_3$	100.09	$C_5H_8O_3$
39	— amino benzoic acid, o	$CH_3CO.NH.C_6H_4COOH$	179.13	$C_9H_9O_3N$

Density H₂O=1.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
>H₂O	s.s.	s.	s.	liq.	185	1
.8902/0°				liq.	169.2	2
.957/0°	s.	s.		−101.2	56.95	3
aq.				liq.	169—171/745	4
	d.	s.	s.	46		5
	i.	s.	s.	70		6
1.0809/15°					190	7
1.0757/21°				liq.	137.9	8
1.20				131/2-3mm.		9
	h.s.	v.s.		159		10
	h.v.s.	s.		132		11
	s.s.	s.	s.	85		12
	v.s.			liq.	d. 100	13
1.0282/20°	s.s.			<−80	181	14
	i.	v.s.	l.	38—40		15
			s.	103		16
	0.86 : 100	s.		112—115	296	17
	0.44 : 100	s.		65.5	303	18
	0.06 : 100	s.		147	307	19
	m.	m.	m.	147		20
						21
.7971/15°	m.	m.	m.	−94.9	56.1	22
.827/16°				−34.6	69.6	23
				−19.5	120	24
	s.s.	s.	s.s.	142—143		25
1.1107/20°	v.s.	v.s.	v.s.	135	d. 250	26
		v.s.		15—16	165/91mm.	27
				190—191		28
.7891	m.	s.		93		29
	m.	m.	m.	−9	190—191	30
.8018/4°	v.s.	v.s.	v.s.	−41	175	31
	s.s.			135		32
1.0272/20°	s.s.			20.8	201.5	33
	c.s.s.			d.		34
						35
	v.s.	v.s.	v.s.	60	135	36
						37
.9745/20°	1 : 8	s.	s.		139—746mm.	38
	c.s.s.	s.	s. acetic	185		39

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Acetyl amino benzoic acid, *m*	$CH_3CO.NH.C_6H_4COOH$	179.13	$C_9H_9O_3N$
2	– – – – *p*	,,	179.13	,,
3	– – phenol, *o*	$CH_3CO.NH.C_6H_4OH$	151.12	$C_8H_9O_2N$
4	– benzoic acid, *o*	$CH_3CO.C_6H_4COOH$	164.11	$C_9H_8O_3$
5	– – –, *p*	,,	164.11	,,
6	– bromide	$CH_3CO.Br$	122.95	C_2H_3OBr
7	– carbazole, **9**	$C_{12}H_8N.COCH_3$	209.17	$C_{14}H_{11}ON$
8	– chloride	$CH_3CO.Cl$	78.49	C_2H_3OCl
9	– disulphide	$(CH_3CO)_2S_2$	160.19	$C_4H_6O_2S_2$
10	– glycine	$CH_3CO.NH.CH_2COOH$	117.09	$C_4H_7O_3N$
11	– hydroxy benzoic acid	$CH_3CO.C_6H_3(OH)COOH$	180.11	$C_9H_8O_4$
12	– indole, 3	$CH_3CO.C_8H_5NH$	159.13	$C_{10}H_9ON$
13	– –, 1	,,	159.13	,,
14	– iodide	$CH_3CO.I$	169.15	C_2H_3OI
15	– isatin	$C_6H_4:(CO)_2:N.COCH_3$	189.12	$C_{10}H_7O_3N$
16	– malonic **ester**	$CH_3CO.CH:(COOC_2H_5)_2$	202.56	$C_9H_{14}O_5$
17	– methyl urea	$CH_3.NH.CO.NH.COCH_3$	116.10	$C_4H_8O_2N_2$
18	– naphthol, *a*	$C_{10}H_7O.COCH_3$	186.14	$C_{12}H_{10}O_2$
19	– –, *β*	,,	186.14	,,
20	– oxamic ester	$CH_3CO.NH.CO.COOC_2H_5$	159.11	$C_6H_9O_4N$
21	– peroxide	$(CH_3CO)_2O_2$	118.07	$C_4H_6O_4$
22	– phenol	$C_6H_5O.COCH_3$	136.10	$C_8H_8O_2$
23	– *p*-phenylene diamine	$NH_2.C_6H_4.NH.COCH_3$	150.14	$C_8H_{10}ON_2$
24	– phenyl hydrazine	$C_6H_5.NH.NH.COCH_3$	150.14	$C_8H_{10}ON_2$
25	– propionic acid	$CH_3CO.C_2H_4.COOH$	116.09	$C_5H_8O_3$
26	– pyrrole	$C_4H_4N.COCH_3$	109.10	C_6H_7ON
27	– quinine	$C_{20}H_{23}O_2N_2.COCH_3$	336.34	$C_{22}H_{26}O_3N_2$
28	– salicylic acid	$COOH.C_6H_4O.COCH_3$	180.11	$C_9H_8O_4$
29	– succinic ester	$CH_3CO.CH(COOC_2H_5)$ $CH_2.COOC_2H_5$	216.18	$C_{10}H_{16}O_5$
30	– thiocyanate	$CH_3CO.SCN$	105.17	C_3H_3ONS
31	– thio-urea	$NH_2.CS.NH.COCH_3$	118.14	$C_3H_6ON_2S$
32	– urea	$NH_2.CO.NH.COCH_3$	102.08	$C_3H_6O_2N_2$
33	Acetylene	$CH:CH$	26.03	C_2H_2
34	– dicarboxylic acid	$COOH.C:C.COOH$	114.04	$C_4H_2O_4$
35	– dichloride, see	Dichlor ethylene		
36	– tetrachloride, see	Tetra chlor ethane		

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	o.s.s.	h.s.	s.s.	248	subl.	1
	s.s.	s.	s.s.	253—254		2
	h.v.s.	v.s.		201		3
	h.s.			114—115		4
	s.s.	s.s.	s.s.	205	subl.	5
					81	6
	s.s.	v.s.	v.s	69	>360	7
1.1051/20°	d.			liq.	51—52/720	8
	i.	s.	s. CS_2	20	d.	9
	2.7 : 100/15°	s.	i.	d. 130		10
	h.s.	s.	s.	129		11
	s.			189	subl.	12
					152—153/14	13
1.98/17°	d.			liq.	108	14
	s.s.	s.	s. C_6H_6	200—201		15
1.080/23°		s.		liq.	238—240	16
	h.s.s	s.s.	s.s.	180—181		17
1.1336/0°		v.s.	v.s.	46	296	18
				70		19
	i.	s.	s.	52—54		20
				30	63/21mm.	21
1.0927/0°					193	22
	c.v.s., h.s.	s.s.	s.s.	162—162.5		23
	s.s.	s.	s.s.	128		24
1.135/15°	v.s.	v.s.	v.s.	33	239	25
	s.s.	s.	s.	90	218	26
		v.s.	v.s.	108		27
	1 : 945	s.	s.	135		28
1.079/ 18—21°	i.	s.		liq.	254—256	29
1.151/16°	d.				132—133	30
	h.s.	s.	s.s.	165		31
		s.	h.s.	214		32
	1 : 1	6 : 1		−81.5		33
	v.s.	v.s.	v.s.	178—179		34
						35
						36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Acetylene tetrabromide, see Tetra brom ethane			
2	— urea	$C_2H_2(CON_2H_2)_2$	142.11	$C_4H_6O_2N_4$
3	Achroodextrine	$C_{36}H_{62}O_{31}$	990.68	$C_{36}H_{62}O_{31}$
4	Aconic acid	$(OH)CH:C(COOH).CH_2.COOH$	146.05	$C_6H_6O_5$
5	Aconine	$C_{25}H_{41}NO_9$	499.46	$C_{25}H_{41}O_9N$
6	Aconitic acid	$C_3H_3(COOH)_3$	174.08	$C_6H_6O_6$
7	Acridine	$C_6H_4\big\langle{\,CH\,\atop N}\big\rangle C_6H_4$	179.15	$C_{13}H_{19}N$
8	Acridone	$C_6H_4\big\langle{\,CO\,\atop NH}\big\rangle C_6H_4$	195.14	$C_{13}H_9ON$
9	Acrolein	$CH_2:CH.CHO$	56.05	C_3H_4O
10	Acrylic acid	$CH_2:CH.COOH$	72.05	$C_3H_4O_2$
11	Adenine, see	Amino-purine		
12	Adipic acid	$COOH.(CH_2)_4.COOH$	146.11	$C_6H_{10}O_4$
13	Adipinketone, see	Cyclopentanone		
14	Æsculetin	$C_9H_6O_4.H_2O$	196.11	$C_9H_8O_5$
15	Æsculin	$2C_{15}H_{16}O_9.3H_2O$	734.46	$C_{15}H_{16}O_9$
16	Alanine, α	$CH_3.CH(NH_2)COOH$	89.08	$C_3H_7O_2N$
17	Aldehyde ammonia,	see Acetaldehyde ammonia		
18	Aldehydin	$CH_3.C_5H_3N(C_2H_5)$	120.13	$C_8H_{10}N$
19	Aldehydo-benzoic acid, o	$COOH.C_6H_4.CHO$	150.09	$C_8H_6O_3$
20	———, m	,, ,,	150.09	,,
21	———, p	,, ,,	150.09	,,
22	— hydroxy-benzoic acid, 3 : 4 : 1	$COOH.C_6H_3OH.CHO$	166.09	$C_8H_6O_4$
23	———, 4 : 3 : 1	,, ,,	166.09	,,
24	———, 3 : 2 : 1	,, ,,	166.09	,,
25	———, 2 : 5 : 1	,, ,,	166.09	,,
26	Aldol	$CH_3.CHOH.CH_2.CHO$	88.08	$C_4H_8O_2$
27	Alizarin, see	Dihydroxy anthraquinone		
28	— amide, o	$C_6H_4:(CO)_2:C_6H_2(OH)NH_2$	239.15	$C_{14}H_9O_3N$
29	— carboxylic acid, 8	$COOH.C_6H_3:(CO)_2:C_6H_2:(OH)_2$	284.14	$C_{15}H_8O_6$
30	— sulphonic acid	$C_{14}H_7O_4(SO_3H)$	320.19	$C_{14}H_8O_7S$
31	Allantoin	$CO\big\langle{NH.CH.NH\,\atop NH.CO.NH}\big\rangle CO$	158.11	$C_4H_6O_3N$

Density H₂O=1.	Solubility in Water	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
						1
	1 : 1075/17°	s.	s. ac.		300 d.	2
	s.	i.				3
	1 : 5.6		s.s.	164		4
	v.s.	v.s.	i.	130		5
	18 : 100	1 : 2	v.s.	191		6
	h.s.s.	s.	s.	107	>360	7
		h.s.s.	i.	354 (corr.)		8
<H₂O 1.0621/16°	1 : 2.5	s.	s.	liq.	50	9
	m.			10.1—10.3	140	10
						11
	1.44 : 100	v.s.	.605 : 100	149	265/100mm.	12
						13
	c.s.s.	s.	s. alk.	d. 270		14
	1 : 670/10°	h. 1 : 24	i.	an. 160 d.		15
	1 : 4.6/17°	1 : 500(80%)c		283—284 d.		16
						17
	i.	s.	s.		180	18
				97		19
				175		20
	s.s.	v.s.	s.s.	246		21
	h.s.s.	s.	s.	234		22
	h.s.	s.	s.	243—244	subl.	23
	1 : 15/100°	s.		179		24
	1 : 150/100°	h.s.s.	s.	248—249		25
1.1094/16°	m.	m.	s.	syrup	83/20mm.	26
						27
	i.	s.	s.	225	subl. 150	28
	v.s.s.	s.	s.s.	321—322	subl.	29
	s.	s.	i.			30
	c. 0.6 : 100 h. 3.3 : 100	s.s.	i.	232—233		31

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Allanturic acid	$NH_2.CO.NH.CO.COOH$	132.07	$C_3H_4O_4N_2$
2	Allocinnamic acid	$C_9H_8O_2$	148.11	$C_9H_8O_2$
3	Allophanate, ethyl	$NH_2.CO.NH.COOC_2H_5$	132.10	$C_4H_8O_3N_2$
4	Alloxan	$CO \genfrac{}{}{0pt}{}{NH.CO}{NH.CO} CO$	142.06	$C_4H_2O_4N_2$
5	Alloxanic acid	$NH_2.CO.NH.CO.CO.COOH$	160.07	$C_4H_4O_5N_2$
6	Alloxantin	$\left[CO \genfrac{}{}{0pt}{}{NH.CO}{NH.CO} \genfrac{}{}{0pt}{}{C}{{}_2C} \right] O$	268.11	$C_8H_6O_7N_4$
7	Allyl acetic acid	$C_3H_5.CH_2.COOH$	100.09	$C_5H_8O_2$
8	— acetone	$CH_3.CO.CH_2.C_3H_5$	98.11	$C_6H_{10}O$
9	— alcohol	$C_3H_5.OH$	58.06	C_3H_6O
10	— amine	$C_3H_5.NH_2$	57.08	C_3H_7N
11	— aniline	$C_6H_5.NH.C_3H_5$	133.14	$C_9H_{11}N$
12	— benzene	$C_6H_5.C_3H_5$	118.13	C_9H_{10}
13	— bromide	C_3H_5Br	120.98	C_3H_5Br
14	— chloride	C_3H_5Cl	76.52	C_3H_5Cl
15	— cyanide	$C_3H_5.CN$	67.07	C_4H_5N
16	— ether	$(C_3H_5)_2:O$	98.11	$C_6H_{10}O$
17	— ethyl ether	$C_3H_5.O.C_2H_5$	86.11	$C_5H_{10}O$
18	— iodide	C_3H_5I	167.98	C_3H_5I
19	— isocyanate	$C_3H_5.NO$	67.07	C_4H_5N
20	— malonic acid	$C_3H_5.CH:(COOH)_2$	144.09	$C_6H_8O_4$
21	— mercaptan	$C_3H_5.SH$	74.12	C_3H_6S
22	— phenyl ether	$C_6H_5.O.C_3H_5$	134.13	C_9H_6O
23	— — urea	$C_6H_5.NH.CO.NH.C_3H_5$	176.16	$C_{10}H_{12}ON_2$
24	— pyridine	$C_3H_5.C_5H_4N$	119.12	C_8H_9N
25	— sulphide	$(C_3H_5)_2:S$	114.17	$C_6H_{10}S$
26	— thiocyanate	$C_3H_5.SCN$	99.13	C_4H_5NS
27	— iso-thiocyanate	$C_3H_5.NSC$	99.13	C_4H_5NS
28	— trisulphide	$(C_3H_5)_2.S_3$	174.26	$C_6H_{10}S_3$
29	Allylene	$CH_3.C:CH$	40.05	C_3H_4
30	— dichloride	$CH_3.CCl:CHCl$	110.97	$C_3H_4Cl_2$
31	Aluminium ethyl	$Al(C_2H_5)_3$	114.15	$C_6H_{15}Al$
32	— methyl	$Al(CH_3)_3$	72.09	C_3H_9Al
33	Amalic acid (tetra-methyl alloxantine)	$(CH_3)_4\ C_8N_4O_7$	324.20	$C_{12}H_{12}O_7N_4$
34	Amino acetal	$NH_2.CH_2CH(OC_2H_5)_2$	133.16	$C_6H_{15}O_2N$

Density $H_2O=1$.	Water.	Solubility in—Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	del.	i.				1
0.845 :				68		2
	h.s. 100/25°		s.s.	191	d.	3
	s.	s.			. 170	4
	s.	1 : 5	s.s.	d.		5
	v.s.s.	v.s.s.	v.s.s.			6
0.9842/15°	s.s.	s.	s.	liq.	182	7
0.832/27°	i.			liq.	239—241/759	8
0.857/15°	m.	s.		liq.	96.6/753mm.	9
0.7631/20°	m	s.		liq.	56.5/756mm.	10
0.982/19°	v.s.s.	s.		oil.	208—209	11
°918/15°		s.		liq.	155	12
1.461/0°	i.				70—71/753	13
0.9379/20°	i.	s		- 136.4	44.6	14
0.849/0°		s.		liq.	119	15
0.8046/18°	i.	s.		liq.	94.3	16
				liq.	64	17
1.85/12°	i.			liq.	102/734mm.	18
0.794/14°	s.s.	s.	s.	liq.	119	19
	s.	s.	s.	103—105	d.	20
	i.	h.s.s.	i.	liq.	90	21
	i.			liq.	193	22
				115		23
0.9595	v.s.	v.s	i		189—190	24
0.88765/26.8°	s.s.			liq.	140	25
1.071/0°	i.			liq.	180—181	26
1.0057/24.2°	s.s.	s.	s.	- 80	150.7	27
1.012/15°	i.	i.	m.		188	28
	s. cupram.		s.	- 110	- 23.5	29
1.23/27°				liq.	55	30
	expl.			- 18	194	31
				liq.	130	32
	h.s.s.	v.s.s.	s. KOH	176 d.		33
	v.s.s.	v.s.s.	v.s.s.		163	34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Amino acetanilide, o	$NH_2.C_6H_4.NH.COCH_3$	150.14	$C_8H_{10}ON_2$
2	— —, m	,, ,,	150.14	,,
3	— —, p	,, ,,	150.14	,,
4	— acetic acid (glycine)	$NH_2.CH_2.COOH$	75.05	$C_2H_5O_2N$
5	— acetophenone, o	$NH_2.C_6H_4.COCH_3$	135.12	C_8H_9ON
6	— —, m	,,	135.12	,,
7	— —, p	,, ,,	135.12	,,
8	— anthraquinone, α	$C_{14}H_7O_2.NH_2$	223.15	$C_{14}H_9O_2N$
9	— —, β	,, ,,	223.15	,,
10	— azobenzene, p	$NH_2.C_6H_4.N_2.C_6H_5$	197.18	$C_{12}H_{11}N_3$
11	— azonaphthalene, α	$C_{10}H_7.N_2.C_{10}H_6.NH_2$	297.25	$C_{20}H_{15}N_3$
12	— —, β	,, ,,	297.25	,,
13	— azotoluene, $CH_3:N:N:CH_3:NH_2$ $=1:2:5:1:2$	$CH_3.C_6H_4.N_2.C_6H_3(NH_2)$ CH_3	225.22	$C_{14}H_{15}N_3$
14	— —, 1:3:5:1:2	,, ,,	225.22	,,
15	— —, 1:4:5:1:2	,, ,,	225.22	,,
16	— —, 1:4:6:1:3	,, ,,	225.22	,,
17	— benzaldehyde, o	$NH_2.C_6H_4.CHO$	121.10	C_7H_7ON
18	— —, m	,, ,,	121.10	,,
19	— —, p	,, ,,	121.10	,,
20	— benzamide, m	$NH_2.C_6H_4.CONH_2$	136.12	$C_7H_{28}ON_2$
21	— —, p	,, ,,	136.12	,,
22	— benzene sulphonic acid o, Anthranilic acid	$NH_2.C_6H_4.SO_3H.\frac{1}{2}H_2O$	182.17	$C_6H_7O_3NS$
23	— — — —, m, Sulphanilic acid	,, ,, $\frac{1}{2}H_2O$	182.17	,,
24	— — — —, p, Metanilic acid	,, ,, $2H_2O$	209.19	,,
25	— benzoic acid, o	$NH_2.C_6H_4.COOH$	137.10	$C_7H_7O_2N$
26	— — —, m	,, ,,	137.10	,,
27	— — —, p	,, ,,	137.10	,,
28	— benzophenone, o	$C_6H_5.CO.C_6H_4.NH_2$	197.16	$C_{13}H_{11}O_2N$
29	— —, m	,, ,,	197.16	,,
30	— —, p	,, ,,	197.16	,,
31	— butyric acid, α	$C_2H_5.CH(NH_2).COOH$	103.10	$C_4H_9O_2N$
32	— — —, β	$CH_3.CH(NH_2)CH_2.COOH$	103.10	,,
33	— camphor	$C_{10}H_{15}O.NH_2$	167.20	$C_{10}H_{17}ON$

Density $H_2O=1$.	Water.	Solubility in—Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	s.s.			145		1
		s.s.		70—100 d.		2
	v.s.	s.s.	s.s.	162—162.5		3
1.1607	23 : 100	0.2 : 100		240	d.	4
					250—252	5
				90		6
	h.s.s.	s.s.	s.s., s.C_6H_6	110 (corr.)	293—295	7
	i.	s.s.	s.s.	243	subl.	8
	i.	s.	i.	302		9
	h.s.s.	s.s.	s.s.	127	225/120mm.	10
	s. H_2SO_4	s.s.	s.s.	173—175		11
				159		12
		s.		100		13
	v.s.s	s.		80		14
	i.	s.		127—128		15
		s.		127		16
	s.s.	v.s.	v.s.	39—40	d.	17
			v.s.			18
	s.	s.		70		19
	s.	s.		75		20
	s.s.	s.		179		21
	1.66 : 100/11°	s.				22
	1 : 68/15°	s				23
	1 : 166/10°			d. 280		24
1.412/20°	h.s.	s.	s.	144.6	d.	25
1.5105/4°	h.s.	s.	s.	174.4		26
1.393/20°	h.s.	s.	s.	186		27
		s.	s.	110—111		28
	s.s.	s.	s.	87		29
	h.s.	s.	s.	124		30
	1 : 3.5	h. 1 : 550		303		31
	del. 1 : 1	s.	i.	184		32
	h.s.	s. ac.		226—228 d.	246.4	33

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Amino caproic acid	$(CH_3)_2:CH.CH_2.CH(NH_2).$ COOH	131.14	$C_6H_{13}O_2N$
2	— iso-caproic acid	,, ,,	131.14	,,
3	— cinnamic acid, o	$NH_2.C_6H_4.C_2H_2.COOH$	163.13	$C_9H_9O_2N$
4	— — —, m	,, ,,	163.13	,,
5	— — —, p	,, ,,	163.13	,,
6	— p-cresol, 3	$NH_2.C_6H_3(OH)CH_3$	123.12	C_7H_9ON
7	— dimethylaniline, p	$NH_2.C_6H_4.N:(CH_3)_2$	136.16	$C_8H_{12}N_2$
8	— diphenyl, o	$C_6H_5.C_6H_4.NH_2$	169.16	$C_{12}H_{11}N$
9	— —, p	,, ,,	169.16	,,
10	— diphenylamine	$NH_2.C_6H_4.NH.C_6H_5$	184.18	$C_{12}H_{12}N$
11	— ethyl alcohol	$NH_2.CH_2.CH_2OH$	61.07	C_2H_7ON
12	— — benzene, o	$C_2H_5.C_6H_4.NH_2$	121.14	$C_8H_{11}N$
13	— — —, p	,, ,,	121.14	,,
14	— guanidine	$NH:C(NH_2)NH.NH_2$	74.09	CH_6N_4
15	— hexahydro benzene	$NH_2.C_6H_5(H_6)$	99.14	$C_6H_{13}N$
16	— β naphthol, 7	$NH_2.C_{10}H_6OH$	159.13	$C_{10}H_9ON$
17	— β —, 1	,, ,,	159.13	,,
18	— α —, 4	,, ,,	159.13	,,
19	— nitro benzoic acid, COOH $: NH_2 : NO_2 =$ 1 : 2 : 5	$C_6H_3(NH_2)(NO_2)COOH$	182.10	$C_7H_6O_4N_2$
20	1 : 2 : 3	,, ,,	182.10	,,
21	1 : 3 : 6	,, ,,	182.10	,,
22	1 : 3 : 2	,, ,,	182.10	,,
23	1 : 3 : 5	,, ,,	182.10	,,
24	1 : 3 : 4	,, ,,	182.10	,,
25	1 : 4 : 3	,, ,,	182.10	,,
26	— — chlor phenol, 2 : 6 : 4	$C_6H_2OH(NH_2)(NO_2)Cl$	188.52	$C_6H_5O_3N_2Cl$
27	— — phenol $NO_2:OH:NH_2=$ 6 : 1 : 2	$C_6H_3OH(NO_2)(NH_2)$	154.10	$C_6H_6O_3N_2$
28	3 : 1 : 2	,, ,,	154.10	,,
29	4 : 1 : 2	,, ,,	154.10	,,
30	— phenol, o	$NH_2.C_6H_4OH$	109.15	C_6H_7ON
31	— —, m	,, ,,	109.15	,,
32	— —, p	,, ,,	109.15	,,
33	— propionic acid, α	$CH_3.CH(NH_2)COOH$	89.08	$C_3H_7O_2N$
34	— — —, β	$CH_2(NH_2)CH_2.COOH$	89.08	,,

Density H₂O=1.	Solubility in Water	Alcohol	Ether	M.P. °C	B.P. °C	
1.293	1 : 46/18°	h.s.s.		170	d.	1
	1 : 117.5	s.s.		214—215		2
	h.s.	s.	s.	158		3
	h.s.	s.	s.	180		4
	h.s.	s.	s.	175—176		5
	i.	s.	s.	135		6
1.0414/15°	s.	v.s.	v.s.	41	262.3	7
	i.	s.		45.5	299	8
-	h.s.	s.s.	s.	53	302	9
	s.s.	s.	s.	75	354	10
1.022/0°	m.	m.			171/757mm	11
0.983/22°				liq.	210—211	12
0.975/22°	s.s.		s.dil.H₂SO₄	liq.	213—214	13
	s.s.	s.s.	i.			14
					134	15
	s.s.	s.	s.	201		16
	h.s.s.		s. fluoresc.			17
	s.d.					18
	h.s.	s.	s.	263 d.		19
	h.s.	v.s.	v.s.	204		20
	h.s.s.	h.s.	—	235 d.		21
	h.v.s.	v.s.	v.s.	156—157		22
	s.s.	h.s.	v.s.	208		23
	s.s.	v.s.	s.	298		24
	i.	h.s.s.		277—278		25
				152		26
	h.v.s.	s.	s. CHCl₃, C₆H₆	110—111		27
	h.s.	s.	s.	76		28
	h.s.	v.s.	v.s.	89—90		29
	1 : 59/0°	1 : 23	s.s.	170	subl.	30
	h.s.	s.	s.	122—123	subl.	31
	1 : 90/0°	1 : 22/0°		184		32
	h.v.s.	0.2 : 100	i.	subl. 200	d. 255	33
	v.s.	s.s.		205—206		34

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Amino purine, 6 (adenine)	$C_5N_5H_5$	135.12	$C_5H_5N_5$
2 — quinoline, α	$C_9H_6N(NH_2)$	144.13	$C_9H_8N_2$
3 — —, β	,, ,,	144.13	,,
4 — salicylic acid, 1:2:5	$NH_2.C_6H_3(OH)COOH$	153.10	$C_7H_7O_3N$
5 — thiazole	$C_3H_2NS.NH_2$	100.13	$C_3H_4N_2S$
6 — thiophen	$C_4H_2S.NH_2$	99.13	C_4H_5NS
7 — thiophenol, o	$NH_2.C_6H_4.SH$	125.16	C_6H_7NS
8 — triphenyl methane	$CH(C_6H_5)_2C_6H_4.NH_2$	259.24	$C_{19}H_{17}N$
9 — succinamic acid	$C_2H_3(NH_2)(COOH)CONH_2$	132.10	$C_4H_8O_3N_2$
10 — succinic acid	$C_2H_3(NH_2)(COOH)_2$	133.09	$C_4H_7O_4N$
11 — valeric acid, α	$CH_3.CH_2.CH_2.CH(NH_2)$ .COOH	117.12	$C_5H_{11}O_2N$
12 — — —, γ	$CH_3.CH(NH_2)CH_2.CH_2.COOH$	117.12	,,
13 — — —, δ	$NH_2.CH_2.CH_2.CH_2.CH_2$ .COOH	117.12	,,
14 — iso-valeric acid, β	$(CH_3)_2:C(NH_2)CH_2.COOH$	117.12	,,
15 — — —, α	$(CH_3)_2:CH.CH(NH_2)COOH$	117.12	,,
16 Ammelide	$(CN)_3NH_2(OH)_2$	128.09	$C_3H_3O_2N_4$
17 Ammeline	$(CN)_3(NH_2)_2OH$	127.11	$C_3H_5ON_5$
18 Amygdalic acid	$C_6H_5.CH(COOH).O$.$C_{20}H_{28}O_{13}$	627.42	$C_{28}H_{35}O_{16}$
19 Amygdalin	$C_6H_5.CH(CN).O.C_{12}H_{21}O_{10}$ $(3H_2O)$	457.33	$C_{20}H_{27}O_{11}N$
20 Amyl alcohol, $norm.$	$C_4H_9.CH_2OH$	88.12	$C_5H_{12}O$
21 — —, iso	$(CH_3)_2:CH.CH_2.CH_2OH$	88.12	$C_5H_{12}O$
22 — —, diethyl carbinol	$(C_2H_5)_2CHOH$	88.12	,,
23 — —, methyl propyl carbinol	$C_2H_5.CH_2.CHOH.CH_3$	88.12	,,
24 — —, methyl $iso.$ propyl carbinol	$(CH_3)_2:CH.CHOH.CH_3$	88.12	,,
25 — —, amylene hydrate	$(CH_3)_2:C(OH).C_2H_5$	88.12	,,
26 — —, $tert.$ butyl carbinol	$(CH_3)_3C.CH_2OH$	88.12	,,
27 — amine, $iso.$	$C_5H_{11}.NH_2$	87.14	$C_5H_{13}N$
28 — aniline, $iso.$	$C_6H_5.NH.C_5H_{11}$	163.20	$C_{11}H_{17}N$
29 — benzene	$C_6H_5.C_5H_{11}$	148.18	$C_{11}H_{16}$
30 — bromide	$C_5H_{11}Br$	151.03	$C_5H_{11}Br$
31 — —, $iso.$	$(CH_3)_2:CH.CH_2.CH_2Br$	151.03	,,
32 — carbylamine	$C_5H_{11}.NC$	97.13	$C_6H_{11}N$
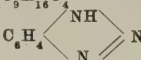
Density H$_2$O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	h.s.	h.s.	i.	d. 360—365		1
	h.s.	h.s.	s.	125		2
	s.	s.	s. ac.	154		3
	s.s.	i.		d. 280		4
	s.s.	s.s.	s.s.	90		5
	v.s.	v.s.	i.			6
				26	234	7
			s.ε.	83—84		8
1.519/14°	s.s.	i.	i.	d.		9
1.6613	1 : 222/20°	i.	s.	270—271		10
	s.	s.s.	i.	291.5 d.		11
	v.s.	s.s.	i.	193	d.	12
	v.s.	s.s.	i.	157—158	d.	13
	v.s.	s.s.	i.	217	subl. 180	14
	s.	i.	i.	298 d.		15
	h. v.s.s.	i.	s. ac.			16
	i.	i.	s. KOH	d.		17
	del.	i.	i.			18
	8 : 100/10°	h.s.	i.	215 an.		19
0.8121/20°	i.			-134	137.5	20
0.825/0°	1 : 39	s.	s.	-134	131.6	21
0.816/18°	i.	s.		112—113.5	116.3/753mm.	22
0.824/0°	1 : 6			liq.	118.5/753mm.	23
0.819/0°	i.			liq.	112.5	24
0.814/15°	s.s.	s.		-12	101.88	25
0.812/20°				53	112	26
0.7503/18°		s.		liq.	95	27
0.928/15°				liq.	259—262	28
0.8602/22°		s.			200.5—201.5/743	29
1.246/0°		s.		liq.	129—130/750	30
1.2358/22°	i.	s.		liq.	120.5—120.8	31
<H$_2$O	i.	s.		liq.	137	32

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Amyl chloride	$C_5H_{11}Cl$	106.57	$C_5H_{11}Cl$
2	—, *iso.*	$(CH_3)_2:CH.CH_2.CH_2Cl$	106.57	,,
3	— cyanide	$C_5H_{11}.CN$	97.13	$C_6H_{11}N$
4	— ether, *iso.*	$(C_5H_{11})_2:O$	155.23	$C_{10}H_{22}O$
5	— ethyl aniline	$C_6H_5.N(C_2H_5)(C_5H_{11})$	191.24	$C_{13}H_{21}N$
6	— ketone, *iso.*	$C_2H_5.CO.C_5H_{11}$	128.17	$C_8H_{16}O$
7	— iodide	$C_5H_{11}I$	198.13	$C_5H_{11}I$
8	—, *iso.*	$(CH_3)_2:CH.CH_2.CH_2I$	198.13	,,
9	— mercaptan	$C_5H_{11}.SH$	104.14	$C_5H_{12}S$
10	— methyl benzene, 1:4	$C_5H_{11}.C_6H_4.CH_3$	162.20	$C_{12}H_{18}$
11	— ether	$C_5H_{11}.OCH_3$	102.14	$C_6H_{14}O$
12	— nitrate, *iso.*	$C_5H_{11}.O.NO_2$	133.12	$C_5H_{11}O_3N$
13	— nitrite, *iso.*	$C_5H_{11}.O.NO$	117.12	$C_5H_{11}O_2N$
14	— phenol, *iso.*, 1:4	$C_5H_{11}.C_6H_4OH$	164.18	$C_{11}H_{16}O$
15	— sulphide	$(C_5H_{11})_2:S$	174.29	$C_{10}H_{22}S$
16	— thiocyanate, *iso.*	$C_5H_{11}.NCS$	129.19	$C_6H_{11}NS$
17	— urethane	$C_5H_{11}.O.CONH_2$	131.14	$C_6H_{13}O_2N$
18	Amylene, ethyl propylene	$CH_3.CH_2.CH:CH.CH_3$	70.11	C_5H_{10}
19	—, trimethylethylene	$(CH_3)_2:C:CH.CH_3$	70.11	,,
20	—, *iso.*	$(CH_3)_2:CH.CH:CH_2$	70.11	,,
21	— glycol	$C_5H_{10}:(OH)_2$	104.12	$C_5H_{12}O_2$
22	Amyloid	$(C_6H_{10}O_5)x$	(162.11)	,,
23	Analgene	$C_7H_5O.NH.C_6H_2(OC_2H_5):C_3H_3N$	292.24	$C_{16}H_{16}O_2N_2$
24	Anethole, 1:4	$CH_3.CH:CH.C_6H_4.OCH_3$	148.15	$C_{10}H_{12}O$
25	Angelic acid	$C_4H_7.COOH$	100.09	$C_5H_8O_2$
26	Anhydroformaldehyde aniline	$C_6H_5.N:CH_2$	105.01	C_7H_7N
27	Aniline	$C_6H_5.NH_2$	93.10	C_6H_7N
28	— hydrochloride	$C_6H_5.NH.HCl$	128.55	C_6H_7NCl
29	Anisalcohol, *p*	$CH_3.O.C_6H_4.CH_2OH$	138.12	$C_8H_{10}O_2$
30	Anisaldehyde, *p*	$CH_3.O.C_6H_4.CHO$	136.10	$C_8H_8O_2$
31	Anisic acid	$CH_3.O.C_6H_4.COOH$	152.10	$C_8H_8O_3$
32	Anisidine, *o*	$CH_3.O.C_6H_4.NH_2$	123.12	C_7H_9ON
33	—, *m*	,, ,,	123.12	,,
34	—, *p*	,, ,,	123.12	,,
35	Anisil, *p*	$CH_3.O.C_6H_4.CO.CO.C_6H_4.OCH_3$	270.19	$C_{16}H_{14}O_4$
36	Anisole	$C_6H_5.OCH_3$	108.10	C_7H_8O

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.9013/0°		s.		liq.	106	1
0.875/15°	i.	s.		liq.	100.9	2
0.866/20°	s.s.	s.	s.	liq.	144—146	3
0.7807/15°	i.			liq.	173	4
				liq.	262	5
0.8502/0°					164—165	6
1.5435/0°		s.		liq.	156	7
1.468/0°		s.		liq.	147	8
0.8548/0°				liq.	116	9
0.8643/0°				liq.	213	10
0.7807/15°				liq.	92	11
1.000/7.5°				liq.	147—148	12
0.902	h.s.s.	s.	s.		97—98	13
	h. v.s.s.			93	265—267	14
0.843/20°		s.s.	s. CHCl₃	liq.	213	15
0.9575/0°				liq.	183—184	16
	s.	s	s.	64.5	220	17
				liq.	39—40	18
0.6783/0°				liq.	36.8/750mm.	19
					21—24	20
0.987/0°	m.	m.	m.	liq.	177	21
	s.s.			42	expl.	22
	i.	c.v.s.s.		206		23
0.989/29°	i.	m.	m.	22.5	232	24
	h.v.s.	s.	s.		185	25
	i.	v.s.s.	s.s.	120		26
1.023/15°	3 : 100	v.s.	v.s.	− 6.2	184.4	27
1.2215/4°	v.s.	v.s.		192	245	28
1.11/26°				45	258.8	29
1.1228/18°	s.s.	m.	m.	0	248	30
1.38/4°	v.s.s.	s.	s.	184.2	275—280	31
1.108/26°		s.	s. ac.	2.5	218	32
					243/755mm.	33
1.0711/55°		s.	s. ac.	57.2	239.5/755mm.	34
		c.v.s.		120		35
1.0124/0°	i.	s.	s.	− 37.8	153.8	36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Anthracene	$C_6H_4 : C_2H_2 : C_6H_4$	178.20	$C_{14}H_{10}$
2	— carboxylic acid, 9	$C_6H_4 : C_2H(COOH) : C_6H_4$	222.16	$C_{15}H_{10}O_2$
3	— — —, 1	$C_6H_4 : C_2H_2 : C_6H_3.COOH$	222.16	,,
4	— — —, 2	,,	222.16	,,
5	— dihydro	$C_6H_4 : C_2H_4 : C_6H_4$	180.17	$C_{14}H_{12}$
6	— hexahydro	$C_{14}H_{16}$	184.20	$C_{14}H_{16}$
7	Anthrachrysone	$C_{14}H_4(OH)_4O_2$ 1:3:5:7	272.13	$C_{14}H_8O_6$
8	Anthraflavic acid, see	Dihydroxy anthraquinone		
9	Anthragallol, see	Trihydroxy anthraquinone		
10	Anthramine	$C_6H_4 : C_2H_2 : C_6H_3.NH_2$	193.17	$C_{14}H_{11}N$
11	Anthranil	$C_6H_4\!\!<\!\!\begin{array}{c}CO\\|\\NH\end{array}$	119.09	C_7H_5ON
12	Anthranilic acid, see	Amino benzoic acid, o		
13	Anthranol	$C_6H_4\!\!<\!\!\begin{array}{c}CH\\ \\C(OH)\end{array}\!\!>\!\!C_6H_4$	194.15	$C_{14}H_{10}O$
14	Anthrapurpurin, see	Trihydroxy anthraquinone		
15	Anthraquinoline	$C_6H_4 : C_2H_2 : C_6H_2\!\!<\!\!\begin{array}{c}CH:CH\\|\\N:CH\end{array}$	229.18	$C_{17}H_{11}N$
16	Anthraquinone	$C_6H_4 : (CO)_2 : C_6H_4$	208.13	$C_{14}H_8O_2$
17	Anthrarufin, see	Dihydroxy anthraquinone		
18	Anthrol	$C_6H_4 : C_2H_2 : C_6H_3.OH$	194.15	$C_{14}H_{10}O$
19	Antimony penta-methyl	$Sb(CH_3)_5$	193.35	$C_5H_{15}Sb$
20	— tri-ethyl	$Sb(C_2H_5)_3$	207.35	$C_6H_{15}Sb$
21	— trimethyl	$Sb(CH_3)_3$	165.29	C_3H_9Sb
22	Antipyrine, 1-phenyl 2 : 3-dimethyl-pyrazolone	$C_6H_5.N.CO.CH$ $||$ $CH_3.N\!\!-\!\!-\!\!-\!\!C.CH_3$	188.17	$C_{11}H_{12}ON_2$
23	Aposafranone, see	Benzene indone		
24	Arabin	$C_{10}H_{18}O_9$	282.19	$C_{10}H_{18}O_9$
25	Arabinose, l.	$C_4H_4(OH)_4CHO$	150.11	$C_5H_{10}O_5$
26	Arabite, l.	$C_5H_7(OH)_5$	152.12	$C_5H_{12}O_5$
27	Arabonic acid, l.	$CH_2OH(CHOH)_3COOH$	166.11	$C_5H_{10}O_6$
28	Arachidic acid	$C_{20}H_{40}O_2$	312.42	$C_{20}H_{40}O_2$
29	Arbutin	$2C_{12}H_{16}O_7.H_2O$	562.40	$C_{12}H_{16}O_7$
30	Arsenic di-ethyl	$As(C_2H_5)_2$	133.06	$C_4H_{10}As$
31	— dimethyl	$As(CH_3)_2$	105.02	C_2H_6As

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C	
1.147	i.	0.076 : 100/16°	s.s.	216.6	351	1
	h.s.s.	s.		206 d.		2
	i.	s.	s.s.	260	subl.	3
		s.s.	s. acetic	>280	subl.	4
	i.	s.	s.	104—105	313	5
	i.	s.	s.	63	290	6
	i.	s.	s.s.	>360		7
						8
						9
	v.s.s.	s.s.	s.s.	238		10
	h.s.	s.	s.		210—215 d.	11
						12
		s.	s.h. alk.	163—170 d.		13
						14
	i.	s.	s.	170	446	15
1.425	i.	0.05 : 100/18°	s.s.	277	379—381	16
						17
	v.s.s.	v.s.	s. acetone	d. 250		18
	i.			96—100		19
1.324	i.	s.	s.	liq.	158.5	20
1.523/15°	s.s.	i.	s.	liq.	80.6	21
	s.	s.	s.s.	114	309/174mm.	22
						23
						24
	v.s.	v.s.s.				24
	s.	i.	i.	160		25
	h.s.			102		26
	s.			89		27
				77.5	238	28
	h.v.s.	s.s.	i.	195		29
>H₂O	i.	s.	s.	liq.	185—190	30
1.15/15°				liq.	149	31

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	Name.	Formula.	Formula Weight.	Empirical Formula
1	Arsenic trimethyl	$As(CH_3)_3$	120.05	C_3H_9As
2	Asparagine, see	Amino succinamic acid		
3	Atrolactic acid	$2CH_3.C(C_6H_5)(OH)COOH$ $.H_2O$	350.27	$C_9H_{10}O_3$
4	Atropic acid	$CH_2:C(C_6H_5)COOH$	148.11	$C_9H_8O_2$
5	Auramine	$C_{17}H_{21}N_3$	267.28	$C_{17}H_{21}N_3$
6	Aurine, Corraline	$(C_6H_4OH)_2:C:C_6H_4:O$	290.21	$C_{19}H_{14}O_3$
7	Azelaïc acid	$C_9H_{16}O_4$	188.17	$C_9H_{16}O_4$
8	Aziminobenzene	$C_6H_4{\diagdown}{\diagup}{\stackrel{NH}{N}}N$	119.10	$C_6H_5N_3$
9	Azobenzene	$C_6H_5.N:N.C_6H_5$	182.16	$C_{12}H_{10}N_2$
10	Azobenzoic acid, o	$C_{14}H_{10}N_2O_4$	270.17	$C_{14}H_{10}O_4N_2$
11	$--$, m	$2C_{14}H_{10}N_2O_4.H_2O$	558.36	,,
12	$--$, p	,, ,,	558.36	,,
13	Azodicarbonamide	$NH_2.CO.N_2.CONH_2$	116.08	$C_2H_4O_2N_4$
14	Azonaphthalene, 2:2′	$(C_{10}H_7)_2N_2$	282.23	$C_{20}H_{14}N_2$
15	$-$, 1:1′	,, ,,	282.23	,,
16	$-$, 1:2′	,, ,,	282.23	,,
17	Azophenol, o	$(C_6H_4OH)_2N_2$	214.16	$C_{12}H_{10}O_2N_2$
18	$-$, p	,, ,,	214.16	,,
19	Azophenetole, o	$(C_6H_4.OCH_3)_2N_2$	246.23	$C_{14}H_{18}O_2N_2$
20	$-$, p	,, ,,	246.23	,,
21	Azophenylene, see	Phenazine		
22	Azotoluene, 2:2′	$(C_7H_7)_2N_2$	210.20	$C_{14}H_{14}N_2$
23	$-$, 3:3′	,, ,,	210.20	,,
24	$-$, 4:4′	,, ,,	210.20	,,
25	Azoxyanisole, p	$(CH_3.O.C_6H_4.N)_2O$	258.20	$C_{14}H_{14}O_3N_2$
26	Azoxybenzene	$(C_6H_5)_2N_2O$	198.16	$C_{12}H_{10}ON_2$
27	Azoxybenzoic acid, o	$C_{14}H_{10}N_2O_5$	286.17	$C_{14}H_{10}O_5N_2$
28	$--$, m	,, ,,	286.17	,,
29	$--$, p	,, ,,	286.17	,,
30	Azoxynaphthalene, 1:1′	$(C_{10}H_7)_2N_2O$	298.23	$C_{20}H_{14}ON_2$
31	$-$, 2:2′		298.23	
32	Azoxyphenetole, p	$(C_2H_5.O.C_6H_4.N)_2O$	286.24	$C_{16}H_{18}O_3N_2$
33	Barbituric acid, see	Malonyl urea		
34	Bassorin	$C_6H_{10}O_5$	162.11	$C_6H_{10}O_5$
35	Behenic acid	$CH_3(CH_2)_{20}COOH$	340.46	$C_{22}H_{44}O_2$
36	Behenolic acid	$C_{22}H_{40}O_2$	336.43	$C_{22}H_{40}O_2$
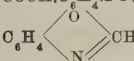
Density $H_2O=1$.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
				liq.	<100	1
						2
	h.m.			93—94		3
	1:692/19°		s. CS_2	106.5	267 d	4
	i.	s.s.	i.	136		5
	i.	s.	s. alk.	d. 220		6
	h.v.s.	v.s	v.s.	106	360	7
1.18—1.23		s.	s. C_6H_6	98.5		8
1.203	i.	s.	s.	68	297	9
	v.s.s.	s.		d. 237		10
	s.s.	s.s.	s.s.		d	11
	i.	i.	i.		d.	12
	v.s.s.	i.		d. 180		13
	i.	s.s.	s. acetic	204		14
	i.		s. acetic	190		15
	i.		s. acetic	136		16
	i.	1 : 300	v.s. KOH	171	subl.	17
	s.s.	s.	s., s. C_6H_6	216—218		18
	i.	s.	s., s. HCl	131	d. 240	19
	i.	h.s.	v.s.	167		20
						21
	i.	s.	s., s. C_6H_6	55		22
	i.	s.	s.	54—55		23
	i.	s.s.	s.	144		24
		s.		117.3		25
1.246/20°	i.	s	s.	36		26
	s.s.	h.s.	s.s..	254—255		27
	i.	s.s.	s.s..	345		28
	i.	i.	s. C_5H_5N	d. 240		29
	i.	i.	i., s. $CHCl_3$	127		30
	i.	i.	i.	167—168		31
		s.		137 (corr.)		32
						33
	s.s.	i.				34
	i.	s. (abs.)		83		35
	i.	v.s.		57.5		36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Benzal acetone	$C_6H_5.C_2H_2.CO.CH_3$	146.13	$C_{10}H_{10}O$
2	— acetophenone	$C_6H_5.C_2H_2.CO.C_6H_5$	208.17	$C_{15}H_{12}O$
3	— acetoacetic ester	$CH_3.CO.C:CH.C_6H_5$ $\quad COOC_2H_5$	218.18	$C_{13}H_{14}O_3$
4	— azine	$C_6H_5.CH:N.N:CH.C_6H_5$	208.19	$C_{14}H_{12}N_2$
5	— chloride	$C_6H_5.CHCl_2$	161.00	$C_7H_6Cl_2$
6	— cyanhydrin	$C_6H_5.CH(OH)CN$	133.11	C_8H_7ON
7	— hydrazine	$C_6H_5.CH:N.NH_2$	120.12	$C_7H_8N_2$
8	— malonic acid	$C_6H_5.CH:C:(COOH)_2$	192.11	$C_{10}H_8O_4$
9	— phenylhydrazone	$C_6H_5.CH:N.NH.C_6H_5$	196.18	$C_{13}H_{12}N_2$
10	Benzaldehyde	$C_6H_5.CHO$	106.08	C_7H_6O
11	— sulphonic acid, o	$CHO.C_6H_4.SO_3H$	186.14	$C_7H_6O_4S$
12	Benzaldoxime, anti	$C_6H_5.CH:N.OH$	121.10	C_7H_7ON
13	—, syn.	,, ,,	121.10	,,
14	— carboxylic acid anhydride, o	$C_6H_4{<}^{CO.O}_{\ \ CH:N}$	147.09	$C_8H_5O_2N$
15	Benzamarone	$C{<}^{C_6H_5CH(C_6H_5).CO.C_6H_5}_{\ \ CH(C_6H_5)CO.C_6H_5}$	480.40	$C_{35}H_{28}O_2$
16	Benzamide	$C_6H_5.CO.NH_2$	121.10	C_7H_7ON
17	Benzamidine	$C_6H_5.C(NH)NH_2$	120.12	$C_7H_8N_2$
18	Benzanilide	$C_6H_5.CONH.C_6H_5$	197.16	$C_{13}H_{11}ON$
19	Benzaurine	$C_6H_5.C:C_6H_4:O$ $\quad C_6H_4OH$	274.21	$C_{19}H_{16}O_3$
20	Benzene	C_6H_6	78.08	C_6H_6
21	— disulphochloride, m	$C_6H_4(SO_2Cl)_2$	275.10	$C_6H_4O_4Cl_2S_2$
22	— hexachloride	$C_6H_6Cl_6$	290.84	$C_6H_6Cl_6$
23	— indone	$C_{18}H_{12}N_2O$	272.21	$C_{18}H_{12}ON_2$
24	— pentacarboxylic acid	$C_6H(COOH)_5.5H_2O$	388.18	$C_{11}H_6O_{10}$
25	— sulphamide	$C_6H_5.SO_2.NH_2$	157.16	$C_6H_7O_2NS$
26	— sulphinic acid	$C_6H_5.SO_2H$	142.14	$C_6H_6O_2S$
27	— sulphochloride	$C_6H_5.SO_2Cl$	176.59	$C_6H_5O_2SCl$
28	— sulphonic acid	$C_6H_5.SO_3H.H_2O$	176.16	$C_6H_8O_4S$
29	— trisulphonic acid	$C_6H_3(SO_3H)_3$	318.26	$C_6H_6O_9S_3$
30	Benzenyl amidoxime	$C_6H_5.C(:NOH)NH_2$	136.20	$C_7H_8ON_2$

Density H₂O=1.	Solubility in— Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.008	i.	s.	s.	41—42	260—262	1
	i.	s.	s.	62	345—348	2
		s.		59—60	181/17mm	3
	i.	h.v.s.	v.s.	93	d.	4
1.295/16°				− 16.1	203.5	5
1.124	i.	s.	s.	S.P. − 10	d 170	6
		s.	s.	16	140/14mm.	7
	s.s.	h.s.	s.s.	d. 195—196		8
		h.s.	s.s.	156	235—239/55	9
1.0455/20°	1 : 300	s.		− 26	179.5	10
	s.			114		11
1.11/20°	s.s.	v.s.	v.s.	20.5	152—153/53	12
			v.s.	128—130		13
				145 becomes		14
				C₆H₄(CN)COOH		
	1 : 157 h.	s.s.	s.s. C₆H₆	219, iso 180		15
1.341/4°	s.s.	s.	s.	130	290	16
	s.	v.s.	s.s.	75—80		17
1.31/4°	i.	s.	s.s.	164		18
	i.	s.	s.	100		19
0.87907/20°	0.2 : 100	s.	s.	5.4	80.2	20
				63	210.7/20mm.	21
1.87/20°		s. CHCl₃	s. C₆H₆	157	288	22
	s.s.	s.	s. C₆H₆	284—249		23
	v.s.			d.		24
	s.s.	h.v.s.	s.	141 d.		25
	h.s.	s.	s	83—84	d. 100	26
1.3830/15°	i.	s.	s.	14.5	d. 247	27
	v.s.	v.s.	i.	65—66	135—137	28
	del.					29
	h.s.	s.	s.	98		30

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Benzenyl amido thiophenol	$C_6H_4 \underset{S}{\overset{N}{<}} C.C_6H_5$	211.21	$C_{13}H_9NS$
2	— naphthylamidine	$C_6H_5.C(NH)NH.C_{10}H_7$	246.22	$C_{17}H_{14}N_2$
3	— phenyleneamidine	$C_6H_5.C \underset{N}{\overset{NH}{<}} C_6H_4$	194.17	$C_{13}H_{10}N_2$
4	Benzhydrol	$(C_6H_5)_2:CHOH$	184.16	$C_{13}H_{12}O$
5	— ether	$[(C_6H_5)_2:CH]_2O$	350.31	$C_{26}H_{22}O$
6	Benzhydroxamic acid	$C_6H_5.C(:NOH)OH$	137.11	$C_7H_7O_2N$
7	Benzhydryl amine	$(C_6H_5)_2:CH.NH_2$	183.18	$C_{13}H_{13}N$
8	— benzoic acid, p	$C_6H_5.OH(OH)C_6H_4.COOH$	228.17	$C_{14}H_{12}O_3$
9	Benzidine, p	$NH_2.C_6H_4.C_6H_4.NH_2$	184.18	$C_{12}H_{12}N_2$
10	— disulphonic acid, o	$(NH_2)_2C_6H_4(SO_3H)_2$	344.30	$C_{12}H_{12}O_6N_2S_2$
11	— sulphone	$C_{12}H_8(NH_2)_2SO_2$	246.22	$C_{12}H_{10}O_2N_2S$
12	Benzil	$C_6H_5.CO.CO.C_6H_5$	210.15	$C_{14}H_{10}O_2$
13	— dioxime, α	$C_6H_5.C(NOH).C(NOH)C_6H_5$	240.19	$C_{14}H_{12}O_2N_2$
14	—, β	„ „	240.19	„
15	—, γ	„ „	240.19	„
16	— monoxin α	$C_6H_5.CO.C(NOH)C_6H_5$	225.17	$C_{14}H_{11}O_2N$
17	—, γ	„	225.17	„
18	— imide	$C_6H_5.C(OH) \overset{O——C.C_6H_5}{\underset{NH.C.C_6H_5}{<}} \;{\Large\|}$	315.25	$C_{21}H_{17}O_2N$
19	— osazone	$C_6H_5.C:N.NH.C_6H_5$ $\|$ $C_6H_5.C:N.NH.C_6H_5$	390.35	$C_{26}H_{22}N_4$
20	Benzilic acid	$(C_6H_5)_2C(OH)COOH$	228.17	$C_{14}H_{12}O_3$
21	Benzimidazole, o	$C_6H_4 \underset{NH}{\overset{N}{<}} CH$	118.10	$C_7H_6N_2$
22	Benzimidazolone, o	$C_6H_4:(NH)_2:CO$	134.10	$C_7H_6ON_2$
23	Benzoic acid	$C_6H_5.COOH$	122.08	$C_7H_6O_2$
24	Benzoate, calcium	$(C_6H_5COO)_2Ca(.3H_2O)$	282.22	$C_{14}H_{16}O_4Ca$
25	—, ferric, basic	$(C_6H_5COO)_6Fe_2(OH)_3$	525.93	$C_{21}H_{18}O_9Fe_2$
26	—, sodium	$C_6H_5.COONa(.H_2O)$	144.08	$C_7H_5O_2Na$
27	—, allyl	$C_6H_5.COOC_3H_5$	162.13	$C_{10}H_{10}O_2$
28	—, amyl iso	$C_6H_5.COOC_5H_{11}$	192.19	$C_{12}H_{16}O_2$
29	—, benzyl	$C_6H_5.COOCH_2.C_6H_5$	212.17	$C_{14}H_{12}O_2$
30	—, ethyl	$C_6H_5.COOC_2H_5$	150.13	$C_9H_{10}O_2$

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.	s.	s.	115	360	1
	i.	s.		141	⌒	2
	s.s.	s.	s. acetic	280		3
	1:2000/20°	v.s.	v.s.	69	297—298/748	4
		s.s.	s. C_6H_6	109	267/15mm.	5
	1:44.5/6°	v.s.	s.s.	124—125		6
				34—35	**303.6**	7
	h.s.	s.	s.	164—165	d.	8
1.251	c.s.s.	s.	s.	128	400/740mm.	9
	s.s.	v.s.s.	v.s.s.			10
	i.	i.	i.	>350		11
	i.	s.	s.	95	347	12
	i.	s.s.	s.s.	237 d.		13
	h.s.s.	s.	s.	206—207 d.		14
	i.	v.s.	s.	165		15
	s.s.	v.s.	v.s.	137—138		16
	i.	v.s.	s.	114		17
		s.		137—138		18
	i.	s.s.	s.s.	225		19
	c.s.s.	s.	s.	150		20
	s.	s.	s. ac., alk.	170		21
	h.s.s.	s.		312		22
1.337	0.29:100/20°	s.	s.	121—122	249.2	23
1.435—1.475	1:27.7/5°					24
	i.					25
	v.s.	1:13				26
					230/768mm.	27
1.004/0°					262	28
1.114/18°		s.		<20	315—320	29
1.0502/16°	h.s.s.	s.	s.	−34.2	212.9/745.5mm.	30

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Benzoate, ethylene	$(C_6H_5.COO)_2C_2H_4$	270.19	$C_{16}H_{14}O_4$
2	—, methyl	$C_6H_5.COOCH_3$	136.10	$C_8H_8O_2$
3	— napthyl, a	$C_6H_5.COO.C_{10}H_7$	248.18	$C_{17}H_{12}O_2$
4	— —, β	,, ,,	248.18	,,
5	— phenyl	$C_6H_5.COOC_6H_5$	198.14	$C_{13}H_{10}O_2$
6	— tolyl, o	$C_6H_5.COOC_6H_4.CH_3$	212.17	$C_{14}H_{12}O_2$
7	— —, m	,, ,,	212.17	,,
8	— —, p	,, ,,	212.17	,,
9	Benzoic anhydride	$(C_6H_5.CO):O$	226.15	$C_{14}H_{10}O_3$
10	Benzoïn, d., l.	$C_6H_5.CH(OH)CO.C_6H_5$	212.17	$C_{14}H_{12}O_2$
11	—, r.	,, ,,	212.17	,,
12	Benzo nitrile	$C_6H_5.CN$	103.09	C_7H_5N
13	— phenone	$(C_6H_5)_2:CO$	182.15	$C_{13}H_{10}O$
14	— — dicarboxylic acid, 2 : 2'	$(C_6H_4.COOH)_2:CO$	270.16	$C_{15}H_{10}O_5$
15	— — oxime	$(C_6H_5)_2:C:NOH$	197.16	$C_{13}H_{11}ON$
16	— trichloride	$C_6H_5.CCl_3$	195.46	$C_7H_5Cl_3$
17	Benzophosphinic acid	$COOH.C_6H_4.PO(OH)_2$ (p)	202.13	$C_7H_7O_5P$
18	Benzoxazole	$C_6H_4\underset{N}{\overset{O}{\diagdown}}CH$	119.09	C_7H_5ON
19	Benzoyl acetic acid	$C_6H_5.CO.CH_2COOH$	164.11	$C_9H_8O_3$
20	— acetone	$C_6H_5.CO.CH_2COCH_3$	162.13	$C_{10}H_{10}O_2$
21	— acetonitrile	$C_6H_5.CO.CH_2CN$	145.11	C_9H_7ON
22	— 1-anthraquinone	$C_6H_4:(CO)_2:C_6H_3.CO.C_6H_5$	312.20	$C_{21}H_{12}O_3$
23	— amino benzoic acid, o	$C_7H_5O.NH.C_6H_4.COOH$	241.17	$C_{14}H_{11}O_3N$
24	— — — —, m	,, ,,	241.17	,,
25	— — — —, p	,, ,,	241.17	,,
26	— azide	$C_6H_5.CO.N\underset{N}{\overset{N}{\diagdown}}$	147.11	$C_7H_5ON_3$
27	— benzoic acid, o	$C_6H_5.CO.C_6H_4COOH.H_2O$	244.22	$C_{14}H_{10}O_3$
28	— — —, m	$C_6H_5.CO.C_6H_4COOH$	226.15	,,
29	— — —, p	,, ,,	226.15	,,
30	— bromide	$C_6H_5.CO.Br$	185.00	C_7H_5OBr
31	— chloride	$C_6H_5.CO.Cl$	140.54	C_7H_5OCl
32	— cyanide	$C_6H_5.CO.CN$	131.09	C_7H_5ON
33	— $cyclo$-butane	$C_6H_5.CO.CH:(CH_2)_2:CH_2$	160.15	$C_{11}H_{12}O$

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.		s.	73—74	>360	1
1.1026/0°	i.			liq.	199.2/746mm.	2
			s.s.	56		3
		h.s.s.	v.s.	107		4
		s.	s.	68—69	314 (corr.)	5
					307	6
				54	313—314	7
				71,5	315.5—316	8
.9555/14.9°	i.	s.	s.	42	360	9
	h.s.s.	s.	s.	131—132.5		10
				129—130		11
1.0052/18°	1 : 100 h.	m.	m.	−17	191.3	12
1.098/50°	i.	s.	s.	47.2		13
	s.s.	s.	s.	>300		14
	i.	s.	s. alk.	139		15
1.38/14°	d.	s.		−21.2	213—214	16
	s.	s.	i.	>300		17
	i.			30.5	182.5	18
	s.s.	v.s.	v.s.	104 d.		19
1.0899/60°	s.s.	v.s.	v.s.	61	260—261	20
		s.	s.	80.5		21
				229		22
	i.	s.	s.	182		23
1.5105/4°	h.s.	s.	s.	174	subl.	24
	s.	s.	s.	265—266		25
	i.	v.s.	v.s.	29—30		26
	h.s.			anhydr. 120		27
	s.s.	v.s.	v.s.	161—162		28
	s.s.	s.	s.	194	subl.	29
1.570/15°		s.		liq.	218—219	30
1.2122/20°	d.	d.	d.	−1	198.3/749mm	31
	d.			32	205—208 d.	32
1.06/4°					258—259/740	33

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Benzoyl *cyclo*-propane	$C_6H_5CO.CH \begin{array}{c} CH_2 \\ \diagdown \\ CH_2 \end{array}$	146.13	$C_{10}H_{10}O$
2	— fluoride	$C_6H_5CO.F$	124.08	C_7H_5OF
3	— formic acid	$C_6H_5CO.COOH$	150.09	$C_8H_6O_3$
4	— glycollic acid	$C_6H_5CO.OCH_2.COOH$	180.11	$C_9H_8O_4$
5	— hydrazine	$C_6H_5CO.NH.NH_2$	136.20	$C_7H_8ON_2$
6	— hydrogen peroxide	$C_6H_5CO.O_2H$	138.08	$C_7H_6O_3$
7	— iodide	$C_6H_5CO.I$	232.00	C_7H_5OI
8	— lactic acid	$CH_3.CH(O.C_6H_5.CO).COOH$	194.13	$C_{10}H_{10}O_4$
9	— naphthylamine, α	$C_7H_5O.NH.C_{10}H_7$	247.20	$C_{17}H_{13}ON$
10	—, β	„ „	247.20	„
11	— peroxide	$(C_6H_5CO)_2O_2$	242.15	$C_{14}H_{10}O_4$
12	— phenetidine, *p*	$C_6H_5O.NH.C_6H_4.OC_2H_5$	241.20	$C_{15}H_{15}O_2N$
13	— phthalic acid, 1:2:3	$C_6H_5CO.C_6H_3(COOH)_2$	270.16	$C_{15}H_{10}O_5$
14	—, tere, 1:2:5	„ „	270.16	„
15	— propionic acid, β	$C_6H_5CO.CH_2.CH_2.COOH$	178.13	$C_{10}H_{10}O_3$
16	— pyrocatechol, see	Dihydroxy benzophenone		
17	— salicin, see	Populin		
18	— sulphide	$(C_6H_5CO)_2:S$	242.21	$C_{14}H_{10}O_2S$
19	— thiourea	$C_6H_5CO.NH.CS.NH_2$	180.18	$C_8H_8ON_2S$
20	— toluidine, *o*	$C_6H_5CO.NH.C_6H_4CH_3$	211.18	$C_{14}H_{13}ON$
21	—, *m*	„ „	211.18	„
22	—, *p*	„ „	211.18	„
23	— urea	$C_6H_5CO.NH.CO.NH_2$	164.12	$C_8H_8O_2N_2$
24	Benzpinacone	$(C_6H_5)_2COH.COH:(C_6H_5)_2$	366.31	$C_{26}H_{22}O_2$
25	Benzyl acetamide	$C_6H_5.CH_2.NH.COCH_3$	149.14	$C_9H_{11}ON$
26	— aceto acetic acid, ethyl ester	$CH_3CO.CH(C_7H_7)COOC_2H_5$	220.19	$C_{13}H_{16}O_3$
27	— alcohol	$C_6H_5.CH_2.OH$	108.10	C_7H_8O
28	— amine	$C_6H_5.CH_2.NH_2$	107.18	C_7H_9N
29	— aniline	$C_6H_5.CH_2.NH.C_6H_5$	183.18	$C_{13}H_{13}N$
30	— azide	$C_6H_5.CH_2.N_3$	133.12	$C_7H_7N_3$
31	— benzoic acid, *o*	$C_6H_5.CH_2.C_6H_4.COOH$	212.17	$C_{14}H_{12}O_2$
32	—, *p*	„ „	212.17	„
33	— bromide	$C_6H_5.CH_2.Br$	171.01	C_7H_7Br
34	— carbamate	$C_6H_5.CH_2.CO_2.NH_2$	151.12	$C_8H_9O_2N$
35	— chloride	$C_6H_5.CH_2.Cl$	126.55	C_7H_7Cl
36	— cyanide	$C_6H_5.CH_2.CN$	117.11	C_8H_7N
37	— cyanamide	$C_6H_5.CH_2.NH.CN$	132.12	$C_8H_8N_2$

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
					239—239.5/720	1
$>H_2O$				liq.	154	2
	s.	s.	s.	75		3
	h.s	s.	s.			4
	v.s.	v.s.	s.s.	112.5		5
	l.	s.	s.	41—43	97—110/15mm.	6
	d.	s.	s.	3	135/25mm.	7
	h.s.	s.	s.	112		8
		v.s. (abs.)		165		9
		h.s.s.	s.s.	157—158		10
	i.	s. C_6H_6	s.	104		11
				173		12
	h.s.	s.		155		13
	i.	s.	s.	>290		14
	h.s.	v.s.	v.s.	116		15
						16
						17
	i.	s.s.	s.	129	d.	18
	s.	s.	i.	71		19
	h.s.s.	s.		131		20
				125		21
		v.s.	s.	158	232	22
	s. KOH	h. 1 : 24	i.	215		23
		h. 1 : 39	s.	185—186		24
	i.	v.s.	v.s.	60—61	>300	25
1.036/14.5°				liq.	283—284	26
1.043/20°	i.	s.	s.	liq	206.5	27
0.9826/18.9°	m.	m.	m.	liq.	183	28
		s.		35.5	298—300	29
	i.	m.	m.		108/25mm.	30
	s.s.	s.	s.	114	subl. 307	31
	s.s.	v.s.	v.s.	154—155	315.5—316	32
1.4380/21°	s.s.	v.s.	v.s.		198—199	33
	s.s.	s.	s.	86	d.	34
1.107/14°	i.	s.	s.	− 41.3	179	35
1.0146/18°	i.	s.	s.	− 24.6	231.7	36
	i.	s.	s.	33		37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Benzyl cyanurate	$(C_6H_5.CH_2.N.CO)_3$	399.32	$C_{24}H_{21}O_3N_3$
2	— diphenyl, a	$C_6H_5.CH_2.C_6H_4.C_6H_5$	244.22	$C_{19}H_{16}$
3	—, p	,,	244.22	,,
4	— diphenylamine	$C_6H_5.CH_2.N:(C_6H_5)_2$	259.24	$C_{19}H_{17}N$
5	— disulphide	$(C_6H_5.CH_2)_2S_2$	246.30	$C_{14}H_{14}S_2$
6	— ether	$(C_6H_5.CH_2)_2O$	198.18	$C_{14}H_{14}O$
7	— ethyl benzene	$C_6H_5.CH_2.C_8H_4.C_2H_5$	196.20	$C_{15}H_{16}$
8	— — ether	$C_6H_5.CH_2.O.C_2H_5$	136.14	$C_9H_{12}O$
9	— hydrazine	$C_6H_5.CH_2.NH.NH_2$	122.14	$C_7H_{10}N_2$
10	— hydroxylamine, a	$C_6H_5.CH_2.NH.OH$	123.12	C_7H_9ON
11	—, β	,,	123.12	,,
12	— iodide	$C_6H_5.CH_2.I$	208.01	C_7H_7I
13	— malonic acid	$C_6H_5.CH_2CH(COOH)_2$	194.13	$C_{10}H_{10}O_4$
14	— mercaptan	$C_6H_5.CH_2.SH$	124.16	C_7H_8S
15	— methyl ether	$C_6H_5.CH_2.CO.CH_3$	134.12	$C_9H_{10}O$
16	— naphthalene, a	$C_6H_5.CH_2.C_{10}H_7$	218.20	$C_{17}H_{14}$
17	—, β	,,	218.20	,,
18	— naphthyl ketone	$C_6H_5.CH_2.CO.C_{10}H_7$	268.23	$C_{18}H_{14}O$
19	— phenanthrene	$C_6H_5.CH_2.C_6H_3:C_2H_2:C_6H_4$	268.23	$C_{21}H_{16}$
20	— phenol, p	$C_6H_5.CH_2.C_6H_4OH$	184.16	$C_{13}H_{12}O$
21	— phenyl carbinol	$C_6H_5CH_2CHOH.C_6H_5$	198.18	$C_{14}H_{14}O$
22	— pyridine, a	$C_6H_5.CH_2.C_5H_4N$	169.16	$C_{12}H_{11}N$
23	—, β	,,	169.16	,,
24	— sulphide	$(C_6H_5.CH_2)_2S$	214.24	$C_{14}H_{14}S$
25	— sulphone	$(C_6H_5.CH_2)_2SO_2$	246.24	$C_{14}H_{14}O_2S$
26	— sulphoxide	$(C_6H_5.CH_2)_2SO$	230.24	$C_{14}H_{14}OS$
27	**tartaric acid**	$C_6H_5.CH_2.C(OH)COOH$	240.15	$C_{11}H_{12}O_6$
		$\qquad$ $CH(OH)COOH$		
28	— thiocyanate	$C_6H_5.CH_2.SCN$	149.11	C_8H_7NS
29	— iso-thiocyanate	$C_6H_5.CH_2.NCS$	149.11	,,
30	— thiourea	$C_6H_5.CH_2.NH.CS.NH_2$	166.20	$C_8H_{10}N_2S$
31	— toluene, m	$C_6H_5.CH_2.C_6H_4.CH_3$	182.18	$C_{14}H_{14}$
32	—, p	,,	182.18	,,
33	— urea	$C_6H_5.CH_2.NH.CO.NH_2$	150.14	$C_8H_{10}ON_2$
34	Benzylidine acetone	$C_6H_5.C_2H_2.COCH_3$	146.13	$C_{10}H_{10}O$
35	— aniline	$C_6H_5.CHN(C_6H_5)$	181.16	$C_{13}H_{11}N$
36	— bromide	$C_6H_5.CHBr_2$	249.94	$C_7H_6Br_2$
37	— diacetate	$C_6H_5.CH:(CH_3COO)_2$	208.18	$C_{11}H_{12}O_4$

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.	s.	s.s.	157		1
		v.s.	v.s.	54	283--287/650	2
		s.	v.s.	85	285—286/650	3
		c.s.s.		87		4
		h.s.	s.	71—72		5
1.0359/16°				oil		6
0.985/19°	s. $CHCl_3$	s.	s.		296	7
		s.			189	8
	s.				135/29mm.	9
					123/50mm.	10
	s.			57		11
1.7335/25°			s.s. CS_2	23	d.	12
	s.s.	s.s.	s.s.	120.6		13
1.058/20°				liq.	195	14
1.010/3°				27	214	15
1.165/0°		h. 1 : 30	1 : 2	58.6	350	16
1 176		1 : 44	s. C_6H_6'	35.5	350	17
		s.	s.	57		18
		s.s.	s. C_6H_6	155—156		19
	s. alk.	s.		84	320—322	20
	i.	s.	v.s.	42		21
					276/742mm.	22
				34	287/740mm.	23
	i.	s.	s.	49—50	170—175/13mm	24
		c.s.s.	s. C_6H_6	150		25
	h.s.	s.	s.	133		26
	s.	s.		143 d.		27
	i.	v.s.	v.s.	40—42	230—235	28
$>H_2O$	i.			liq.	240—245	29
	s.			103—104		30
0.997/17.5°		s.	s.	liq.	268—269.5/20	31
0.995/17.5°		s.	s.	− 20	278—280	32
	h.s.	s.		150.5—151.5	d.	33
1.008		s.	s.	41—42	260—262	34
	i.	v.s.	v.s.	50	300	35
					130—140/20	36
		v.s.	v.s.	45	220	37

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Benzylidine phthalide	$C_6H_4.C:CH.C_6H_5$ $CO\!-\!O$	222.16	$C_{15}H_{10}O_2$
2 Berberonic acid	$C_5H_2N(COOH)_3+H_2O$	229.11	$C_8H_5O_6N$
3 Betaïne	$N(CH_3)_3.CH_2.CO\ (+H_2O)$	101.12	$C_5H_{11}ON$
4 Bilirubin	$C_{32}H_{36}N_{ }O_6$	572.49	$C_{32}H_{36}O_6N_4$
5 Biliverdin	$C_{32}H_{36}N_{ }O_8$	604.49	$C_{32}H_{36}O_8N_4$
6 Bismuth tri-ethyl	$Bi(C_2H_5)_3$	296.15	$C_6H_{15}Bi$
7 Biuret	$NH:(CONH_2)_2$	103.08	$C_2H_5O_2N_3$
8 Borneol	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
9 Bornyl amine	$C_{10}H_{17}NH_2$	153.21	$C_{10}H_{19}N$
10 — chloride	$C_{10}H_{17}Cl$	172.65	$C_{10}H_{17}Cl$
11 Brasileïn	$C_{16}H_{12}O_5$	302.20	$C_{16}H_{12}O_5$
12 Brasilin	$C_{16}H_{14}O_5$	304.21	$C_{16}H_{14}O_5$
13 Brassylic acid, α β	$C_9H_{18}(COOH)_2$	216.22	$C_{11}H_{20}O_4$
14 Bromo-acetamide	$CH_3.CO.NHBr$	137.97	C_2H_4ONBr
15 — acetanilide, o	$Br.C_6H_4.NH.COCH_3$	214.03	C_8H_8ONBr
16 — —, m	,, ,,	214.03	,,
17 — —, p	,, ,,	214.03	,,
18 — acetic acid	$CH_2Br.COOH$	138.95	$C_2H_3O_2Br$
19 — acetate, ethyl	$CH_2Br.COOC_2H_5$	167.00	$C_4H_7O_2Br$
20 — acetophenone	$C_6H_5.CO.CH_2Br$	199.02	C_8H_7OBr
21 — acetotoluide, 5:2	$Br.C_7H_6.NH.COCH_3$	228.05	$C_9H_{10}ONBr$
22 — —, 3:4	,, ,,	228.05	,,
23 — acetyl bromide	$CH_2Br.CO.Br$	201.87	$C_2H_2OBr_2$
24 — — chloride	$CH_2Br.COCl$	157.41	C_2H_2OClBr
25 — acetylene	C_2HBr	104.94	C_2HBr
26 — allyl alcohol	$CH_2:CBr.CH_2OH$	136.98	C_3H_5OBr
27 — aniline, o	$Br.C_6H_4.NH_2$	172.01	C_6H_6NBr
28 — —, m	,, ,,	172.01	,,
29 — —, p	,, ,,	172.01	,,
30 — anthraquinone, 1	$C_6H_4:(CO)_2:C_6H_3Br$	287.05	$C_{14}H_7O_2Br$
31 — — 2	,, ,,	287.05	,,
32 — benzene	$C_6H_5.Br$	156.09	C_6H_5Br
33 — benzoic acid, o	$Br.C_6H_4.COOH$	201.00	$C_7H_5O_2Br$
34 — — —, m	,, ,,	201.00	,,
35 — — —, p	,, ,,	201.00	,,
36 — butyric acid, α	$CH_3.CH_2.CHBr.COOH$	167.00	$C_4H_7O_2Br$
37 — iso-butyric acid, α	$(CH_3)_2:CBr.COOH$	167.00	,,

Density $H_2O=1$.	Water.	Solubility in— Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.	h.s.		99, *iso* 91		1
	h.s.	h.s.s.	t.	235		2
	61.8 : 100 /25°	s.	i.			3
	i.	v.s.s.	v.s.s.	192—192.5		4
	i.	s.	s.s.			5
2.3/15°	i.	s.	s.	liq.	16.	6
	s.	s.		190 d.		7
1.011	i.	s.	s.	205	212	8
	s.s.	v.s.	v.s.	159—160		9
	d. 40°	v.s.	v.s.	158		10
	s. alk.	s.				11
	s.	s.	s.			12
	s.s.			90—91		13
	s.	s.	i.	91		14
		s.		99		15
		s.s.	s.s.	84		16
	c.i.	s.s.		168		17
	s.			49—50	208	18
					159	19
		v.s.	v.s.	51		20
				156—157		21
				117		22
2.317/21.5°					149—150	23
1.908/0°					127—127.5	24
				gas		25
1.6/15°					155	26
		s.		31—31.5	250—251	27
		s.		18—18.5	251	28
		s.		66.4	d.	29
		s.		204—205	subl.	30
		s.e.	s.h. C_6H_6	188	subl.	31
		s.		− 31.1	156.15	32
1.929/20°	s.	v.s.	v.s.	150		33
1.845/20°	s.s.	v.s.	v.s.	155	>280	34
1.894/20°	v.s.s.	v.s.	v.s.	251		35
1.54/15°	1 :15			81	137—137.5/50 mm.	36
				29	198—200	37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Bromo camphor	$C_{10}H_{15}OBr$	231.09	$C_{10}H_{15}OBr$
2	— cinnamic acid, α	$C_6H_5.CH:CBr.COOH$	227.02	$C_9H_7O_2Br$
3	— — —, β	$C_6H_5.CBr:CH.COOH$	227.02	,,
4	— ethylene	$CH_2:CHBr$	106.95	C_2H_3Br
5	— hexahydrobenzene	$C_6H_5Br(H)_6$	163.04	$C_6H_{11}Br$
6	— naphthalene, α	$C_{10}H_7Br$	207.03	$C_{10}H_7Br$
7	— —, β	,, ,,	207.03	,,
8	— nitro benzene, o	$Br.C_6H_4.NO_2$	201.99	$C_6H_4O_2NBr$
9	— — —, m	,, ,,	201.99	,,
10	— — —, p	,, ,,	201.99	,,
11	— phenol, o	$Br.C_6H_4OH$	172.99	C_6H_5OBr
12	— —, m	,, ,,	172.99	,,
13	— —, p	,, ,,	172.99	,,
14	— phenyl hydrazine, p	$Br.C_6H_4.NH.NH_2$	187.02	$C_6H_7N_2Br$
15	— phthalic acid, 5	$Br.C_6H_3:(COOH)_2$	242.00	$C_8H_5O_4Br$
16	— propionic acid, α	$CH_3.CHBr.COOH$	152.98	$C_3H_5O_2Br$
17	— styrol, α	$C_6H_5.CH:CHBr$	183.02	C_8H_7Br
18	— —, β	$C_6H_5.CBr:CH_2$	183.02	,,
19	— succinic acid	$COOH.CHBr.CH_2.COOH$	196.98	$C_4H_5O_4Br$
20	— toluene, o	$CH_3.C_6H_4.Br$	171.01	C_7H_7Br
21	— —, m	,, ,,	171.01	,,
22	— —, p	,, ,,	171.01	,,
23	— toluidine, $NH_2:Br=2:5$	$CH_3.C_6H_3(Br)NH_2$	186.03	C_7H_8NBr
24	— —, 3:6	,, ,,	186.03	,,
25	— —, 4:3	,, ,,	186.03	,,
26	— iso-valeric acid	$(CH_3)_2:CH.CHBr.COOH$	181.02	$C_5H_9O_2Br$
27	Bromal	$CBr_3.COH$	280.78	C_2HOBr_3
28	Bromoform	$CHBr_3$	252.77	$CHBr_3$
29	Butane, $norm.$	$CH_3.CH_2.CH_2.CH_3$	58.10	C_4H_{10}
30	—, trimethylmethane	$CH(CH_3)_3$	58.10	,,
31	Butyl alcohol, $norm.$	$CH_3.CH_2.CH_2.CH_2OH$	74.10	$C_4H_{10}O$
32	— —, $iso.$	$(CH_3)_2:CH.CH_2OH$	74.10	,,
33	— —, ethyl methyl carbinol	$C_2H_5.CHOH.CH_3$	74.10	,,
34	— —, trimethyl carbinol	$(CH_3)_3COH$	74.10	,,
35	— amine, $norm$	$C_4H_9.NH_2$	73.12	$C_4H_{11}N$
36	— —, $sec.$	$CH_3.CH(NH_2)CH_2.CH_3$	73.12	,,
37	— benzene, $norm.$	$C_6H_5.C_4H_9$	134.10	$C_{10}H_{14}$

Density H₂O=1.	Solubility in — Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.437	s. C_6H_6	s.s.	s. CS_2	76	274	1
		m.	m.	130—131		2
	h.s.	v.s.	v.s. CS_2	120		3
1.53/11°				liq.	16/750mm.	4
					162—163/714 d.	5
1.488/16°	m. C_6H_6	m. (abs.)	m.	liq.	277	6
1.605/0°	s. C_6H_6	v.s.	v.s.	59	281—282	7
		s. oleum.		41	261	8
	v.s.s.	s.s.		54	256.5	9
		i. oleum.		126	255—256	10
				S.P. 5.6	194—195	11
				32—33	236—236.5	12
1.840/15°	s. $CHCl_3$	v.s.	v.s.	63.5	238	13
				107		14
	v.s.	v.s.	v.s.	138—40		15
				25.7—27.1	205.5 (corr.)	16
					150—160/75	17
				7	219—221	18
	1:5.2/15°			159		19
1.4222/20°				— 25.9	180.3/754	20
1.4099/20°		s.		— 39.8	183.7	21
1.3898/20°		s.	s.	26.5	183.6/758	22
				58—59	240	23
				78.4—78.8	240	24
1.510/20°				26	240	25
	s.s.			44	230 d.	26
3.34	d.			liq.	172.5—173	27
2.9045/15°	i.			7.8	146.5/757.5	28
	i.	18 vol.:1		— 135	0.6	29
0.6				— 145	— 10.2	30
0.8094/0°	1:12		s. HCl	liq.	116.9	31
0.8057/15°	1:10.5/18°			liq.	107.4	32
0.819/22°	s.			liq.	101/745mm.	33
0.7887/20°	m.			25	82.9	34
0.7401/20°	m.	s.	s.	liq.	75.5	35
0.7557/15°	m.			liq.	63	36
0.875/0°					186	37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Butyl benzene, *iso.*	$C_6H_5.C_4H_9$	134.16	$C_{10}H_{14}$
2	— —, *sec.*	,,	134.16	,,
3	— choral	$C_4H_5Cl_3O$	175.44	$C_4H_5OCl_3$
4	— — hydrate	$C_4H_5Cl.O.H_2O$	193.46	$C_4H_7O_2Cl_3$
5	— chloride, *norm.*	$CH_3.CH_2.CH_2.CH_2Cl$	92.55	C_4H_9Cl
6	— —, *iso.*	$(CH_3)_2:CH.CH_2Cl$	92.55	,,
7	— —, *tert.*	$(CH_3)_3CCl$	92.55	,,
8	— cyanide, *norm.*	$CH_3.CH_2.CH_2.CH_2CN$	83.11	C_5H_9N
9	— —, *iso.*	$(CH_3)_2:CH.CH_2CN$	83.11	,,
10	— —, *tert.*	$(CH_3)_3C.CN$	83.11	,,
11	— ether	$(C_4H_9)_2:O$	130.18	$C_8H_{18}O$
12	— ethyl ether	$C_4H_9.O.C_2H_5$	102.14	$C_6H_{14}O$
13	— iodide, *norm*	$CH_3.CH_2.CH_2.CH_2I$	184.01	C_4H_9I
14	— —, *iso.*	$(CH_3)_2:CH.CH_2I$	184.01	,,
15	— —, *sec.*	$CH_3CH_2.CHI.CH_3$	184.01	,,
16	— —, *tert.*	$(CH_3)_3CI$	184.01	,,
17	— mercaptan	C_4H_9SH	90.16	$C_4H_{10}S$
18	— sulphide, *norm.*	$(CH_3.CH_2.CH_2.CH_2)_2S$	146.24	$C_8H_{18}S$
19	— —, *sec.*	$(CH_3.CH_2.CH.CH_3)_2S$	146.24	,,
20	— thiocyanate, *norm.*	$CH_3.CH_2.CH_2.CH_2.NCS$	115.17	C_5H_9NS
21	— —, *iso.*	$(CH_3)_2:CH.CH_2.NCS$	115.17	,,
22	— —, *sec.*	$CH_3.CH_2.CH(NCS)CH_3$	115.17	,,
23	— —, *tert.*	$(CH_3)_3C.NCS$	115.17	,,
24	Butylene, *norm.*	$CH_3.CH_2.CH:CH_2$	56.08	C_4H_8
25	—, *iso.*	$(CH_3)_2:C:CH_2$	56.08	,,
26	—, *pseudo.*	$CH_3.CH:CH.CH_3$	56.08	,,
27	— bromide, β	$CH_3CHBr.CHBr.CH_3$	215.92	$C_4H_8Br_2$
28	— glycol, *norm.*	$CH_3.CH_2.CHOH.CH_2OH$	90.10	$C_4H_{10}O_2$
29	— —, β	$CH_3.CHOH.CH_2.CH_2OH$	90.10	,,
30	— —, *iso.*	$(CH_3)_2:COH.CH_2OH$	90.10	,,
31	Butyramide, *norm.*	$CH_3.CH_2.CH_2.CONH_2$	87.10	C_4H_9ON
32	—, *iso.*	$(CH_3)_2:CH.CONH_2$	87.10	,,
33	Butyric acid, *norm.*	$CH_3.CH_2.CH_2.COOH$	88.08	$C_4H_8O_2$
34	— —, *iso.*	$(CH_3)_2:CH.COOH$	88.08	,,
35	Butyrate, amyl	$C_3H_7.COO.C_5H_{11}$	158.19	$C_9H_{18}O_2$
36	—, ethyl	$C_3H_7.COOC_2H_5$	116.13	$C_6H_{12}O_2$
37	— —, *iso.*	$(CH_3)_2:CH.COOC_2H_5$	116.13	,,
38	— methyl	$C_3H_7.COOCH_3$	102.11	$C_5H_{10}O_2$
39	— —, *iso.*	$(CH_3)_2:CH.COOCH_3$	102.11	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P °C.	
0.8578/15°					167.5	1
0.8726/16°					170—172	2
1.395/20°	d.			liq.	164—165/750	3
1.693	h.s.	v.s.		78	d.	4
0.8874/20°				liq.	77.96	5
0.8336/15°				liq.	68.5	6
0.847/15°				liq.	51—52	7
0.816/0°				liq.	140.4/739	8
0.8227/0°	s.s			liq.	129.3	9
				15—16	105—106	10
0.7685/20°				liq.	140.5	11
0.7522/2°					91.7	12
1.6166/20°				liq.	131.4/745.4	13
1.6401/0°				liq.	120/745.4	14
1.6263/0°				liq.	118	15
1.571/0°	d			liq.	98—99	16
0.858/0°				liq.	92	17
0.8523/0°	i.			liq.	182	18
0.8317/23°				liq.	165	19
				liq.	167	20
0.9638/14°				liq.	162	21
0.944/12°				liq.	159.5	22
0.9187/10°				10.5	140	23
					- 5	24
	s. H₂SO₄				- 6	25
0.635/—13°	i. H₂SO₄				+1/741.4mm	26
1.821/0°					158	27
1.019/0°	v.s.	m.		liq.	191—192/747 mm	28
1.0259	v.s.	s.	i.	liq.	203.5—204	29
1.0129/0°	s.			liq.	176—178	30
	v.s.	s.	s.	116	216	31
	v.s.	s.	s.s.	127.5	216—220	32
0.9746/0°	m.	m.	m.	- 8	162.3	33
0.9487/19.8°	1 : 5			- 79	155.5	34
0.8832	s.s.	v.s.	v s.	liq.	178.6	35
0.8807/18°	0.5 : 100	s.	s.	- 80	119.9	36
0.8710/20°	i.	s.		- 116	110.1	37
0.9194/0°		s.		liq.	102—102.5	38
0.911/0°		s.	s.	liq.	92.4	39

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Butyric aldehyde, *norm*	$CH_3.CH_2.CH_2.CHO$	72.08	C_4H_8O
2	— —, *iso.*	$(CH_3)_2:CH.CHO$	72.08	,,
3	— anhydride, *norm.*	$(C_4H_7O)_2:O$	158.15	$C_8H_{14}O_3$
4	Butyrolactone, γ	$C_4H_6O_2$	86.07	$C_4H_6O_2$
5	Butyrone	$(C_3H_7)_2CO$	114.15	$C_7H_{14}O$
6	Butyryl chloride, *norm*	$CH_3.CH_2.CH_2.COCl$	106.54	C_4H_7OCl
7	— —, *iso.*	$(CH_3)_2:CH.COCl$	106.54	,,
8	Cacodyl	$(CH_3)_2As_2(CH_3)_2$	210.04	$C_4H_{12}As_2$
9	— chloride	$(CH_3)_2AsCl$	140.48	C_2H_6ClAs
10	— oxide	$[(CH_3)_2As]_2O$	226.04	$C_4H_{12}OAs_2$
11	— sulphide	$[(CH_3)_2As]_2S$	242.10	$C_4H_{12}SAs_2$
12	— trichloride	$(CH_3)_2AsCl_3$	211.40	$C_2H_6Cl_3As$
13	Cacodylic acid	$(CH_3)_2AsO.OH$	138.03	$C_2H_7O_2As$
14	Cadaverine, see	Pentamethylene diamine		
15	Camphane	$C_{10}H_{18}$	138.19	$C_{10}H_{18}$
16	Camphene, l.	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
17	—, d.	,,	136.18	,,
18	Campholenic acid, d.	$C_{10}H_{18}O_2$	170.19	$C_{10}H_{18}O_2$
19	Camphor, l.	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
20	—, d.	,,	152.18	,,
21	Camphoric acid	$C_5H_7(CH_3)_3(COOH)_2$	200.18	$C_{10}H_{16}O_4$
22	Camphoronic acid, d.	$C_9H_{14}O_6$	218.16	$C_9H_{14}O_6$
23	Camphor oxime, l.	$C_{10}H_{16}:NOH$	167.20	$C_{10}H_{17}ON$
24	Camphylamine	$C_9H_{15}.CH_2.NH_2$	153.21	$C_{10}H_{19}N$
25	Cane sugar, sucrose	$C_{12}H_{22}O_{11}$	342.24	$C_{12}H_{22}O_{11}$
26	Cantharidin	$C_{10}H_{12}O_4$	196.14	$C_{10}H_{12}O_4$
27	Capric acid	$C_9H_{19}.COOH$	172.21	$C_{10}H_{20}O_2$
28	Caprate, ethyl	$C_9H_{19}.COOC_2H_5$	200.25	$C_{12}H_{24}O_2$
29	Caproic acid, *norm.*	$C_5H_{11}.COOH$	116.13	$C_6H_{12}O_2$
30	— —, *iso.*	$(CH_3)_2:CH.CH_2.CH_2.COOH$	116.13	,,
31	— —, diethyl acetic acid	$(C_2H_5)_2:CH.COOH$	116.13	,,
32	— —, dimethyl ethyl acetic acid	$(CH_3)_2(C_2H_5)C.COOH$	116.13	,,
33	Capronate, ethyl	$C_5H_{11}.COOC_2H_5$	144.17	$C_8H_{16}O_2$
34	Capronitrile	$C_5H_{11}CN$	97.13	$C_6H_{11}N$
35	Caprylic acid	$C_7H_{15}.COOH$	144.17	$C_8H_{16}O_2$
36	Caprylate, ethyl	$C_7H_{15}.COOC_2H_5$	172.21	$C_{10}H_{20}O_2$
37	Carbamide chloride	$CO(NH_2)Cl$	74.09	CH_2ONCl
38	Carbamidine, see	Guanidine		

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.8170/20°	1 : 27			liq.	73—74	1
0.7938/20°	1 : 9/20°			liq.	63/741mm.	2
0.978/15.5°				liq.	191—193	3
1.1441/0°	m.	s.s.	s.s.		203.5—204	4
0.82/20°	i.			liq.	142	5
1.0277/20°				liq.	99—101/734.4	6
1.0174/20°				liq.	91.5—92.5/748.2	7
$>H_2O$	s.s.	s.	s.	− 6	170	8
$>H_2O$	i.			liq.	100	9
1.462	s.s.			− 25	120	10
	s.	s.			211	11
	d.					12
	v.s.	s.			200	13
						14
				158—159	160—161/763	15
0.879/60°				51—52	158.5—159.5	16
				50—51	158—159	17
	s. oils	1 : 0.8	v.s.	95	250	18
0.992/10°	s.s. acetic	s.	s.	172	204/757mm.	19
				176.4	209.1	20
1.193	h. 1 : 12	c. 1 : 0.89		187 (corr.)	d.	21
	s.	s.	s.s.	158—159 d.		22
		v.s.	v.s.	115	d. 250	23
0.93/37°					194—196	24
1.5881/20°	190 : 100/10°	s.s.		160	d.	25
	i.	c. 0.03 : 100	0.11 : 100	218		26
0.930/27°	h.s.s.	s.	s.	31	266—268	27
0.862				liq.	243—245	28
0.929/20°	s.s.			− 1.5	205	29
0.9237/20°	s.s.				199.7	30
0.9196/15°	s.s.			liq.	190.1	31
	i.			− 14	187	32
0.8728/20°	i.	s.	m.	liq.	214	33
0.866/20°	s.s.	m.	s.	liq.	144—146	34
0.9270/0°	1 : 400/100°	m.	m.	16.5	232—234	35
0.8730/16°	d.			liq.	205.8	36
	i.	i.		50	61—62	37
						38

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Carbanile	$C_6H_5.N:CO$	119.09	C_7H_5ON
2	Carbanilide	$CO:(NH.C_6H_5)_2$	212.18	$C_{13}H_{12}ON_2$
3	Carbazide	$CO:(NH.NH_2)_2$	90.09	CH_6ON_4
4	Carbazole	$(C_6H_4)_2:NH$	167.15	$C_{12}H_9N$
5	Carbodiphenylimide, a	$C_6H_5.N:C:N.C_6H_5$	194.11	$C_{13}H_{10}N_2$
6	—, β	,, ,,	194.11	,,
7	—, γ	,, ,,	194.11	,,
8	Carbon tetrachloride	CCl_4	153.84	CCl_4
9	Carbostyril	$C_6H_4{<}{\overset{NH}{\underset{C_2H_2}{\ }}}{>}CO$	145.11	C_9H_7ON
10	Carboxy phenyl thioglycollic acid, o	$C_6H_4.(COOH).(S.CH_2.COOH)$	212.17	$C_9H_8O_4S$
11	Carbyl sulphate	$\overline{CH_2.O.SO_2.O.SO_2.CH_2}$	188.16	$C_2H_4O_6S_2$
12	Carminic acid	$C_{17}H_{18}O_{10}$	382.23	$C_{17}H_{18}O_{10}$
13	Carnine	$C_7H_8N_4O.H_2O$	182.16	$C_7H_8ON_4$
14	Carvacrol, 5 : 2 : 1	$C_6H_3(C_3H_7)(CH_3)OH$	150.16	$C_{10}H_{14}O$
15	Carvenone	$CH_3.CH{<}{\overset{CH_2.CH_2}{\underset{CO.OH}{\ }}}{>}C.CH:(CH_3)_2$	152.18	$C_{10}H_{16}O$
16	Carvomenthene	$C_{10}H_{18}$	138.19	$C_{10}H_{18}$
17	Carvomenthol	$C_{10}H_{19}OH$	156.21	$C_{10}H_{20}O$
18	Carvone, d.	$CH_3C{<}{\overset{CH.CH_2}{\underset{CO.CH_2}{\ }}}{>}CH.C{<}{\overset{CH_3}{\underset{CH_2}{\ }}}$	150.16	$C_{10}H_{14}O$
19	Caryophyllene	$C_{15}H_{24}$	204.27	$C_{15}H_{24}$
20	Catechin	$C_{15}H_{14}O_6$	290.19	$C_{15}H_{14}O_6$
21	Cedrene	$C_{15}H_{24}$	204.27	$C_{15}H_{24}$
22	Cellulose	$(C_6H_{10}O_5)x$	(162.11)	
23	Cerotic acid	$C_{26}H_{52}O_2$	396.55	$C_{26}H_{52}O_2$
24	Ceryl alcohol	$C_{26}H_{54}O_2$	382.56	$C_{26}H_{54}O_2$
25	Cetyl alcohol	$C_{16}H_{34}O$	242.35	$C_{16}H_{34}O$
26	Cetylene	$C_{16}H_{32}$	224.34	$C_{16}H_{32}$
27	Chelidonic acid	$C_5H_2O_2(COOH)_2$	184.67	$C_7H_4O_6$
28	Chinophenol, see	Hydroxy quinoline		

Density $H_2O=1$.	Solubility in—Water.	Alcohol.	Ether.	M.P. °C	B.P. °C	
1.092/15°	d.			liq.	166	1
	s.s.	s.	s.	239—240		2
				152—153		3
	i.	0.92 : 100/14°	s.	subl. 238	338	4
		h.d.	d.		163—165/11mm	5
				158—160	235—236/65mm	6
				96—98		7
1.582/21°	i.			−23.8	76.7	8
	h.s.	v.s.	v.s.	199—200	subl.	9
				212—214		10
	del. d.			80		11
	v.s.	s	s.s.			12
	h.s.	i	i.			13
0.9856/15°		s		0	236—237	14
0.927					235.5—236	15
0.8230/16.5°					174—175	16
0.908/20°					220	17
0.953/15°				liq.	227—228	18
	i.	s.s		258—260	subl. 280	19
	h.s.	s.	s.	235—237	d.	20
0.9359/15°				liq.	237	21
	s. cupram.					22
	i.	i.	i.	76—77	d.	23
	i.	s.	s.	79	305/20mm.	24
0.8176/49°	i.	s.	s.	50—51	174—175/10	25
0.8039/20°				20	160/15mm.	26
	s.	s.	s.s.	d. 262		27
						28

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Chlor-acetanilide, o	$C_6H_4Cl.NH.COCH_3$	169.57	C_8H_8ONCl
2	——, m	,, ,,	169.57	,,
3	——, p	,, ,,	169.57	,,
4	——, ω	$C_6H_5.NH.CO.CH_2Cl$	169.57	,,
5	— acetic acid	$CH_2Cl.COOH$	94.49	$C_2H_3O_2Cl$
6	— acetate, ethyl	$CH_2Cl.COOC_2H_5$	122.54	$C_4H_7O_2Cl$
7	— acetone	$CH_3.CO.CH_2Cl$	92.52	C_3H_5OCl
8	— acetyl chloride	$CH_2Cl.CO.Cl$	112.95	$C_2H_2OCl_2$
9	— acetylene	C_2HCl	60.48	C_2HCl
10	— acrylic acid, α	$CH_2:CCl.COOH$	106.50	$C_3H_3O_2Cl$
11	——, β	$CHCl:CH.COOH$	106.50	
12	— aniline, o	$C_6H_4Cl.NH_2$	127.55	C_6H_6NCl
13	——, m	,, ,,	127.55	,,
14	——, p	,, ,,	127.55	,,
15	— anthraquinone, 1	$C_6H_4.(CO)_2:C_6H_3Cl$	242.59	$C_{14}H_7O_2Cl$
16	—— 2	,, ,,	242.59	,,
17	— benzaldehyde, o	$Cl.C_6H_4.CHO$	140.54	C_7H_5OCl
18	——, m	,, ,,	140.54	,,
19	——, p	,, ,,	140.54	,,
20	— benzene	C_6H_5Cl	112.53	C_6H_5Cl
21	— benzoic acid, o	$C_6H_4Cl.COOH$	156.54	$C_7H_5O_2Cl$
22	———, m	,, ,,	156.54	,,
23	———, p	,, ,,	156.54	,,
24	benzyl chloride, p	$C_6H_4Cl.CH_2Cl$	161.00	$C_7H_6Cl_2$
25	———, o	,, ,,	161.00	,,
26	— camphor	$C_{10}H_{16}Cl_2$	207.10	$C_{10}H_{16}Cl_2$
27	— carbonic ester	$COCl(OC_2H_5)$	108.52	$C_3H_5O_2Cl$
28	— crotonic acid, α	$CH_3.CH:CCl.COOH$	120.52	$C_4H_5O_2Cl$
29	———, β	$CH_3.CCl:CH.COOH$	120.52	,,
30	———, γ	$CH_2Cl.CH:CH.COOH$	120.52	,,
31	— dinitro benzene, 1:3:4α	$C_6H_3Cl(NO_2)_2$	202.53	$C_6H_3O_4N_2Cl$
32	1:3:4 β	,, ,,	202.53	,,
33	1:3:4 γ	,, ,,	202.53	,,
34	1:2:6	,, ,,	202.53	,,
35	1:2:4	,, ,,	202.53	,,
36	1:3:5	,, ,,	202.53	,,
37	—— phenol, 4:2:6:1	$C_6H_2Cl(NO_2)_2.OH$	218.53	$C_6H_3O_5N_2Cl$
38	— diphenyl, o	$C_6H_4Cl.C_6H_5$	188.59	$C_{12}H_9Cl$
39	——, m	,, ,,	188.59	,,

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
		s.	s. C_6H_6	87—88		1
		s.	s. C_6H_6	72,5		2
1.385/22°		s.	s.	175		3
		s.s. acetic	ss.	135		4
1.3947/73°	s.			62.5—63.2	186	5
1.1585/20°				liq.	143.5	6
0.5158/13°	s.s.	m.	m.	liq.	119	7
1.495					106	8
				gas		9
	m.	s.	s.	65	d. 176—181	10
			s. C_6H_6	84—85		11
1.2125/20°	12:100/15°			S.P. -2.1	208.8	12
1.2149/20°				S.P. -10.4	230	13
1.1704/70°				70.5	232.3	14
		s.		162		15
		s.	v.s.C_6H_6	208		16
				110	208/748mm.	17
				17—18	213—214	18
	c.s.s.; h.s.	s.s.	s.s.	48—49	213/748mm.	19
1.1115		s.		-45	132	20
1.544/20°	0.21:100/25°	s.		139.5		21
	1:2840/0°	s.		156	subl.	22
1.541/24°	1:5288/0°	s.	s.	234—240	subl.	23
	h.v.s.		v.s.	29	213—214 (222)	24
					213—214	25
		s.	v.s.	155—155.5		26
1.144/15°				liq.	93.1	27
	597:100/19°	v.s.	v.s.	99.5	212	28
				94—94.5	206—211	29
				76.5—77.5	117—118/13mm.	30
		s.	s.	36.3 to γ		31
		s.		37.1 to γ		32
		s.	s.	38.8		33
1.678/16°		v.s.	s.	42	315	34
1.697/22°		s.		50	315	35
		s.	s.	53		36
				80.5		37
			s. ligroin	34	267—268	38
				89		39

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Chlor diphenyl, p	,, ,,	188.59	,,
2	— hydrin, a	$CH_2Cl.CHOH.CH_2OH$	110.53	$C_3H_7O_2Cl$
3	——, β	$CH_3.CCl(OH).CH_2OH$	110.53	,,
4	— malonic acid	$CHCl:(COOH)_2$	138.50	$C_3H_3O_4Cl$
5	— methyl ether	$CH_2Cl.O.CH_3$	80.51	C_2H_5OCl
6	—— sulphate	$CH_2Cl.HSO_4$	146.55	CH_3O_4SCl
7	— naphthalene, a	$C_{10}H_7Cl$	162.57	$C_{10}H_7Cl$
8	——, β	,,	162.57	,,
9	— nitro benzene, o	$C_6H_4Cl(NO_2)$	157.53	$C_6H_4O_2NCl$
10	———, m	,, ,,	157.53	,, ,,
11	———, p	$C_6H_4Cl(NO_2)$	157.53	$C_6H_4O_2NCl$
12	—— naphthalene, 4 : 1	$C_{10}H_6Cl(NO_2)$	207.57	$C_{10}H_6O_2NCl$
13	———, 7 : 1	,, ,,	207.57	,,
14	—— phenol, OH : Cl : $NO_2 = 1:6:2$	$C_6H_4OH(NO_2)Cl$	173.53	$C_6H_4O_3NCl$
15	1 : 5 : 2	,, ,,	173.53	,,
16	1 : 4 : 2	,, ,,	173.53	,,
17	1 : 2 : 4	,, ,,	173.53	,,
18	1 : 4 : 3	,, ,,	173.53	,,
19	1 : 5 : 3	,, ,,	173.53	,,
20	1 : 6 : 3	,, ,,	173.53	,,
21	— phenol, o	$C_6H_4Cl.OH$	128.53	C_6H_5OCl
22	——, m	,, ,,	128.53	,,
23	——, p	,, ,,	128.53	,,
24	— phthalic acid, 4	$C_6H_4Cl(COOH)_2$	200.54	$C_8H_5O_4Cl$
25	— propionic acid, a	$CH_3.CHCl.COOH$	108.52	$C_3H_5O_2Cl$
26	———, β	$CH_2Cl.CH_2.COOH$	108.52	,,
27	— pyridine, 2	$C_5H_4N.Cl$	113.53	C_5H_4NCl
28	——, 3	,,	113.53	,,
29	——, 4	,,	113.53	,,
30	— quinoline, 2	$C_9H_6N.Cl$	163.56	C_9H_6NCl
31	——, 4	,,	163.56	,,
32	— toluene, o	$C_6H_4.(Cl)CH_3$	126.55	C_7H_7Cl
33	——, m	,, ,,	126.55	,,
34	——, p	,, ,,	126.55	,,
35	— trinitro-benzene, 5 : 1 : 2 : 4	$C_6H_2Cl(NO_2)_3$	247.54	$C_6H_2O_6N_3Cl$
36	2 : 1 : 3 : 5	,, ,,	247.54	,,

Density H₂O=1.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
			s. ligroin	75.5	282	1
	s.				213	2
					146/18mm.	3
	s.s.	s.s.	s.s.	133	d. slow. 180	4
	d.			F.Pt. -103.5	59.1—59.3/766mm.	5
						6
1.2028/6.4°		s.	s. CS₂	liq.	250—252	7
1.2656/16°		s.		56	264—266/751mm	8
1.368/22°	i.	s.		32.5	243	9
1.534	i.	h.s.	v.s.	44.4	235.6	10
1.380/22°	i.	s.		83	242	11
	i.	s.	s.	85		12
	i.	s.		116		13
	s.s.		s. CHCl₃	70		14
				38.9		15
	v.s.s.	s.	s., s. CHCl₃	86—87		16
	v.s. CHCl₃	v.s.	v.s.	110—111		17
				126—127		18
				147		19
				118—119		20
		s.		7	175	21
		s.	s.	32—33	214	22
1.306/20.5°	s.s.	v.s.	v.s.	37	217	23
	s.s.	s.		148		24
1.28/0°	m.	s.		liq.	186	25
	v.s.	v.s.		41.5	203—205	26
	s.			liq.	166/714mm.	27
				liq.	148/743.5mm	28
	s.			liq.	147—148	29
1.2754/16.6°	i.	s.	v.s.	37—38	275/751mm.	30
1.3766/16.6°		s.	s.	34	260—261/744mm	31
1.0807/20°				-34	159.4	32
1.07218/20°				-47.8	162.2	33
				7.4	162.3	34
		s.s.		116		35
1.790/22°	i.	h.s.	s.s.	83		36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Chloral	$CCl_3.COH$	147.40	C_2HOCl_3
2	— alcoholate	$CCl_3.CH(OC_2H_5)OH$	193.46	$C_4H_7O_2Cl_3$
3	— hydrate	$CCl_3.CH(OH)_2$	165.41	$C_2H_3O_2Cl_3$
4	Chloranil	$C_6Cl_4O_2$	245.87	$C_6O_2Cl_4$
5	Chloroform	$CHCl_3$	119.39	$CHCl_3$
6	Chloropicrin	$C(NO_2)Cl_3$	164.40	CO_2NCl_3
7	Cholesterol	$C_{26}H_{44}OH$	372.48	$C_{26}H_{44}O$
8	— benzoate	$C_{26}H_{43}.O.C_7H_5O$	476.55	$C_{33}H_{48}O_2$
9	Cholic acid	$C_{24}H_{40}O_5.H_2O$	426.46	$C_{24}H_{40}O_5$
10	Choline	$C_2H_4OH.N(CH_3)_3OH$	121.16	$C_5H_{15}O_2N$
11	Chrysamminic acid	$C_6H_2(NO_2)_4(OH)_2O_2$	420.14	$C_{14}H_4O_{12}N$
12	Chrysaniline	$C_{19}H_{15}N_3$	285.25	$C_{19}H_{15}N_3$
13	Chrysarobin	$C_{15}H_{12}O_2$	224.17	$C_{15}H_{12}O_2$
14	Chrysazine, see	Dihydroxy anthraquinone		
15	Chrysazol, see	Dihydroxy anthracene		
16	Chrysene	$C_{18}H_{12}$	228.19	$C_{18}H_{12}$
17	Chrysine	$C_{15}H_{10}O_4$	254.16	$C_{15}H_{10}O_4$
18	Chryso-quinone, 1 : 2	$C_{18}H_{10}O_2$	258.17	$C_{18}H_{10}O_2$
19	— —, 2 : 8	„	258.17	„
20	Chrysophanic acid	$C_{14}H_6O_2(OH)_2CH_3$	254.16	$C_{15}H_{10}O_4$
21	Cinchomeronic acid	see Pyridine dicarboxylic acid		
22	Cineol	$C_{10}H_{18}$	154.19	$C_{10}H_{18}O$
23	Cineolic acid	$C_{10}H_{16}O_5$	216.18	$C_{10}H_{16}O_5$
24	Cinnamic acid	$C_6H_5.CH:CH.COOH$	148.11	$C_9H_8O_2$
25	Cinnamate, benzyl	$C_6H_5.CH:CH.COO.C_7H_7$	238.19	$C_{16}H_{14}O_2$
26	—, ethyl	$C_6H_5.CH:CH.COO.C_2H_5$	176.15	$C_{11}H_{12}O_2$
27	Cinnamic acid chloride	$C_6H_5.CH:CH.COCl$	166.56	C_9H_7OCl
28	— aldehyde	$C_6H_5.CH:CH.CHO$	132.11	C_9H_8O
29	— alcohol	$C_6H_5.CH:CH.CH_2OH$	134.13	C_9H_8O
30	— anhydride	$(C_9H_7O)_2:O$	278.20	$C_{18}H_{14}O_3$
31	— carboxylic acid, o	$COOH.C_6H_4.CH:CH.COOH$	192.11	$C_{10}H_8O_4$
32	Citraconic acid	$C_3H_4(COOH)_2$	130.07	$C_5H_6O_4$
33	— anhydride	$C_3H_4:(CO)_2:O$	112.06	$C_5H_6O_3$
34	Citral	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
35	Citramalic acid	$COOH(CH_3):C(OH).CH_2.COOH$	148.09	$C_5H_8O_5$
36	Citrene	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
37	Citric acid	$C_3H_4(OH)(COOH)_3.H_2O$	210.11	$C_6H_8O_7$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.512/20°	v.s.	s.		−57.5	97.7	1
1.143/40°	s. d.	s.		46	115	2
1.5745/66°	s.	s.	s. CS_2	47.4	96—98 d.	3
	i.	h.s.s.	s.s.	290	subl.	4
1.5039/11.8°	v.s.s.	s.	s.	−63.2	61.2	5
1.0697/20°	i.	3.7 : 1		−64	111.9	6
1.067	i.	h. 1 : 9	s., s. CS_2	145—146		7
		i.	s.	146.6		8
	v.s.s.	s.	s.s.	197		9
	s.	v.s.	v.s.			10
	i.	s.	s.			11
	s.s.	s.s.		267—270		12
	i.	s.	s. $CHCl_3$	170—178		13
						14
						15
	s.s.	0.097 :100/16°	s. acetic	250	448	16
	s. alk.	c. 1 : 180	s.s.	275	subl.	17
	s. H_2SO_4	h.s.	s.s.	237	subl.	18
				288—290 d.		19
	i.	h. 1 : 24	s.	196	subl.	20
						21
0.9267/20°	d.			−1	176	22
	c. 1 : 70		s.	196—197 d.		23
1.249	0.0546 : 100/25°	s.	v.s.	133	300	24
				39	225—235	25
1.0498/20°		s.		12	271	26
				35—36	170—171/58	27
1.0497/24°		s.	s.	−7.5	126—127/15	28
1.044/20°	s.s.	v.s.	v.s.	33	250	29
	i.	s.s.		136		30
	s.s.	s.	s.s.	173—175		31
1.617	1 : 0.42/15°			80	91 d.	32
1.2504/15°				7	213	33
0.8972/15°	i.				224—225 d.	34
	s.	s.	s.	119	d. 130	35
0.85/15°		s.		liq.	168—168.5	36
1.542	c. 133 : 100	87 : 100	9.1 : 100	153, an. 100	d.	37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Citronellal	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
2	Citronellol	$C_{10}H_{20}O$	156.21	$C_{10}H_{20}O$
3	Cœrulein	$C_{20}H_{12}O_6$	348.20	$C_{20}H_{12}O_6$
4	Cœrulignone	$C_{16}H_{16}O_6$	340.21	$C_{16}H_{16}O_6$
5	Collidine, α	$C_5H_2N(CH_3)_3$	121.14	$C_8H_{11}N$
6	—, β	,, ,,	121.14	,,
7	—, γ	,, ,,	121.14	,,
8	Coniferin	$C_{16}H_{22}O_8.2H_2O$	378.29	$C_{16}H_{22}O_8$
9	Coniferyl alcohol	$C_{10}H_{12}O_3$	180.15	$C_{10}H_{12}O_3$
10	Conylene	C_8H_{14}	110.15	C_8H_{14}
11	Coumalic acid	$C_5H_3O_2(COOH)$	140.06	$C_6H_4O_4$
12	Coumalin	$CH \diagup{}^{CH:CH}_{CH.CO}\diagdown O$	96.06	$C_5H_4O_2$
13	Coumaric acid, o	$C_6H_4(OH)C_2H_2.COOH$	164.11	$C_9H_8O_3$
14	——, p	,, ,,	164.11	,,
15	Coumarin	$C_6H_4 \diagup{}^{CH:CH}_{O——CO}$	146.10	$C_9H_6O_2$
16	Creatine	$NH_2.C(:NH).N(CH_3).CH_2$ $COOH(.H_2O)$	131.12	$C_4H_9O_2N_3$
17	— $iso.$, methyl glycocyamide	$C_4H_9N_3O_2$	131.12	,,
18	Creatinine, methyl glycocyamidine	$NH:C \diagup{}^{NH——CO}_{N(CH_3).CH_2}$	113.11	$C_4H_7ON_3$
19	Cresol, o	$CH_3.C_6H_4.OH$	108.10	C_7H_8O
20	—, m	,, ,,	108.10	,,
21	—, p	,, ,,	108.10	,,
22	Cresorcinol, see	Dihydroxy toluene		
23	Cresotinic acid, see	Hydroxy toluic acid		
24	Croconic acid	$C_5O_3(OH)_2(3H_2O)$	142.04	$C_5H_2O_5$
25	Crotonaldehyde, α	$CH_3.CH:CH.CHO$	70.07	C_4H_6O
26	Crotonic acid, α	$CH_3.CH:CH.COOH$	86.07	$C_4H_6O_2$
27	——, β	$CH_2:CH.CH_2.COOH$	86.07	,,
28	Crotonyl alcohol	$CH_3.CH:CH.CH_2OH$	72.08	C_4H_8O
29	Crotonylene	$CH_3.C:C.CH_3$	54.07	C_4H_6
30	Cubebine	$C_{20}H_{20}O_6$	356.26	$C_{20}H_{20}O_6$

Density H$_2$O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °O.	
0.8538/17 5°					205—208	1
0.8565/17.5°					221—222	2
	v.s.s.	s.s.	s. alk.			3
	h.s.	i.	s. H$_2$SO$_4$	d.		4
0.929/0°	s.s.	s.	s.	liq.	180	5
0.966/0°	i.	s.		liq.	195—196	6
0.917/15°	i.	s	s.	liq.	171—172	7
	h.s.	s.	i.	185	d.	8
	h.s.s.	s.	s.	73—74		9
0.76/15°		s.			125	10
	c.s.s.	s.	s.s.	205—210 d.	subl.	11
1.2	m.	s .	s.	5	206—209 d.	12
	h.s.	s.	v.s.s.	214	d.	13
	c.v.s.s.	v.s.	v.s.	215		14
0.9348/7.3°	s.s.	v.s.	s.	70	301	15
	h.s.	i.		220 d.		16
	1 : 12	h.s.s.		d. 220		17
	s.	h.s.				18
1.0427/23.2°	s.s.	s.	s.	30	190.8	19
1.0350/13.6°	s.s.	s.	s.	3—4	200.5	20
1.0340/17.7°	s.s.	s.	s.	36	201.1	21
						22
						23
	v.s.	s.		an. 100		24
0.8557/17.3°	s.			liq.	103—104	25
1.018	1 : 12/15°		s. ligroin.	71—72	180—181	26
1.018	m.				172	27
					117—120	28
	i.	s. cupram.		liq.	27.2—27.6	29
	v.s.s.	1.31 :	3.75/100	131—132		30

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Cumarone	$C_6H_4 \diagdown^{O}_{CH} \diagup CH$	118.09	C_8H_6O
2 Cumene	$C_6H_5.CH:(CH_3)_2$	120.14	C_9H_{12}
3 Cumidic acid	$(CH_3)_2:C_6H_2:(COOH)_2$	194.13	$C_{10}H_{10}O_4$
4 Cumidine, 1:2:4:5	$(CH_3)_3C_6H_2.NH_2$	135.16	$C_9H_{13}N$
5 —, amino iso-propyl benzene	$C_3H_7.C_6H_4.NH_2$	135.16	,,
6 Cumin alcohol, p	$C_3H_7.C_6H_4.CH_2OH$	150.16	$C_{10}H_{14}O$
7 — aldehyde, cuminol	$C_3H_7.C_6H_4.CHO$	148.15	$C_{10}H_{12}O$
8 Cuminic acid	$C_3H_7.C_6H_4.COOH$	164.15	$C_{10}H_{12}O_2$
9 Cumylic acid, 1:2:4:5	$(CH_3)_3C_6H_2.COOH$	164.15	$C_{10}H_{12}O_2$
10 Curcumin	$C_{14}H_{14}O_4$	246.18	$C_{14}H_{14}O_4$
11 Cyamelide	$(CNOH)x$	(43.03)	
12 Cyan-acetic acid	$CH_2CN.COOH$	85.05	$C_3H_3O_2N$
13 — amide	$NC.NH_2$	42.04	CH_2N_2
14 — anilide	$C_6H_5.NH.CN$	118.10	$C_7H_6N_2$
15 — aniline	$(C_6H_7N)_2(CN)_2$	238.20	$C_{14}H_{14}N_4$
16 — carbonic ester	$CN.COOC_2H_5$	99.07	$C_4H_5O_2N$
17 — naphthalene, α	$C_{10}H_7CN$	153.12	$C_{11}H_7N$
18 ——, β	,,	153.12	,,
19 — propionic acid, α	$CH_3.CH(CN)COOH$	99.07	$C_4H_5O_2N$
20 — sulphide	$(CN)_2:S$	84.09	C_2N_2S
21 — uramide	$C_3N_3(NH_2)_2$	110.10	$C_3H_2N_5$
22 Cyanethine	$CH_3.C-CH=C.NH_2$ $\parallel \qquad \mid$ $N.C(CH_3)=N$	123.13	$C_6H_9N_3$
23 Cyanogen	C_2N_2	52.03	C_2N_2
24 — chloride, liq.	$CN.Cl$	61.48	$CNCl$
25 ——, solid	$C_3N_3Cl_3$	184.43	$C_3N_3Cl_3$
26 Cyanuric acid, iso.	$C_3N_3(OH)_3.2H_2O$	165.10	$C_3H_3O_3N_3$
27 Cyclo heptane	C_7H_{14}	98.15	C_7H_{14}
28 — heptanone, suberone	$CO \diagup^{CH_2CH_2CH_2}_{CH_2CH_2CH_2}$	112.13	$C_7H_{12}O$
29 — hexane	$C_6H_6(H_6)$	84.13	C_6H_{12}
30 —— dione, 1:3	$C_6H_4O_2(H_4)$	112.09	$C_6H_8O_2$
31 ———, 1:4	,, ,,	112.09	,, ,,
32 — hexanol	$C_6H_5(H_6)OH$	100.13	C_6H_{12}

Density H$_2$O=1.	Solubility in Water	Alcohol	Ether	M.P. °C	B.P. °C	
1.0767/15°	i.	100/12°		liq.	171—172	1
0.866/15°	i.	s.	s.	−75.1	152.5—**153.5**	2
	s.s.	h.s.	v.s.	>320		3
0.9526	s.	s.		64	225	4
	s.	s.	s. C_6H_6		213.5—214.5/ 732mm.	5
0.9775/15°	s.s.	m.	m.	liq.	246.6	6
0.9832	h.s.	s.	s.	liq.	237	7
1.1625/4°	0.015 : 100/25°	s.	s.	117	subl.	8
	h.s.s.	v.s	s., s. C_6H_6	149—150		9
	s. alk.	s.	s.	178		10
	i.				d.	11
	i.	v.s.	v.s.	69	d.	12
	v.s.	v.s.	v.s.	41—42	143—144/18	13
	s.s.	s.	s.	47		14
	i.	s.s.	s.s.	214	d.	15
	i.	s.	s.	liq.	115—**116**	16
		s.		33.5	296.5	17
		s.		66.5	304—305	18
	v.s.	v.s.		d. 140		19
	s.	s.	s.	60	d.	20
	s.s.	i.	i.	subl. d.		21
	s.			180—181	subl.	22
>H$_2$O	4.5 : 1 vol.	22 : 1 vol.		−35	−21	23
	s.s.	s.	s.	15.5		24
1.32			s.	145	190	25
	1 : 40	s.				26
0.8904/20°				−13 to −12	117—117.5/ 743mm.	27
					179—181	28
0.7237/20°				6.5	80.7	29
	d.	s.s.	s.s.	105—106		30
	v.s.s.	s.s.	s.s.	78		31
	1 :28 o.			25	161.1	32

M

	Name.	Formula.	Formula Weight.	Empirical Formula
1	Cyclo hexene	$C_6H_6(H_4)$	82.11	C_6H_{10}
2	— pentane	$CH_2 \begin{array}{c} CH_2CH_2 \\ \mid \\ CH_2CH_2 \end{array}$	70.10	C_5H_{10}
3	— pentanone, adipinketone	$CO \begin{array}{c} CH_2CH_2 \\ \mid \\ CH_2CH_2 \end{array}$	84.09	C_5H_8O
4	Cymene, p	$CH_3.C_6H_4.C_3H_7$	134.16	$C_{10}H_{14}$
5	—, o	,,	134.16	,,
6	—, m	,, ,,	134.16	,,
7	Dambose	$C_6H_{12}O_6.2H_2O$	216.16	$C_6H_{12}O_6$
8	Daphnetin	$C_9H_6O_4$	178.09	$C_9H_6O_4$
9	Deca hydro-naphthalene	$C_{10}H_8(H_{10})$	138.19	$C_{10}H_{18}$
10	— — quinoline	$C_9H_7N(H_{10})$	139.19	$C_9H_{17}N$
11	Decane, $norm.$	$C_{10}H_{22}$	142.23	$C_{10}H_{22}$
12	Decyl alcohol, $norm.$	$C_{10}H_{21}OH$	158.23	$C_{10}H_{22}O$
13	Dehydracetic acid	$CH.CO.CH.CO.CH$ $\mid \quad \parallel$ $CO. O. C.CH_3$	168.10	$C_8H_8O_4$
14	Desoxalic acid	$C_2H(OH)_2(COOH)_3$	194.07	$C_5H_6O_8$
15	Desoxybenzoin	$C_6H_5.CO.CH_2.C_6H_5$	196.17	$C_{14}H_{12}O$
16	Dextrin	$C_6H_{10}O_5$	162.11	$C_6H_{10}O_5$
17	Dextrose	$C_6H_{12}O_6$	180.13	$C_6H_{12}O_6$
18	Diacetamide	$(CH_3CO)_2:NH$	101.09	$C_4H_7O_2N$
19	Diacetanilide	$(CH_3CO)_2:N.C_6H_5$	177.15	$C_{10}H_{11}O_2N$
20	Diacethydroquinone	$C_6H_2O_2(CH_3CO)_2$	194.13	$C_{10}H_{10}O_4$
21	Diacetin	$C_3H_5OH(O.COCH_3)_2$	176.13	$C_7H_{12}O_5$
22	Diacetyl	$CH_3.CO.CO.CH_3$	86.09	$C_4H_6O_2$
23	— acetic ester	$(CH_3CO).CH.COOC_2H_5$	129.10	$C_6H_9O_3$
24	— catechol	$(CH_3.CO.)_2:C_6H_4$	194.13	$C_{10}H_{10}O_4$
25	— hydroquinone	,, ,,	194.13	,,
26	— glucose	$C_5H_6(OCH_3.CO)_2(OH)_3.$ COH	264.18	$C_{10}H_{16}O_8$
27	— m-phenylene diamine	$C_6H_4:(NH.CO.CH_3)_2$	192.16	$C_{10}H_{12}O_2N_2$
28	— resorcin	$(CH_3.CO.)_2:C_6H_4$	194.13	$C_{10}H_{10}O_4$
29	— succinic acid, diethyl ester	$C_2H_2(COCH_3)_2(COOC_2H_5)_2$	258.20	$C_{12}H_{18}O_6$

Density H₂O=1.	Solubility in Water	Alcohol	Ether	M.P. °C	B.P. °C	
0.8102/20°					83—84	1
0.751/20°					49—50	2
						3
					130—130.5	
0.852/15°	i.	s.	s.	− 73.5	175	4
0.858	i.	s.			157	5
0.865	i.	s.			175—176	6
1.524	v.s.	i. (abs.)		225	319	7
	h.v.s.	h.s.	v.s.s.	d. 253—256		8
0.837/19°					187—188	9
	h.s.	v.s.	s.	48.2—48.5	204/714mm	10
0.7342/15°				− 30 to − 32	173	11
0.8389/7°	s.	s.	v.s.	7	231	12
	s.	h.s.		108.5—109	269.9	13
	v.s.	v.s.	s.	liq.	d.	14
	s.s.	s.	s.	60—61	320—322	15
1.03845	s.	i. (abs.)				16
1.54— 1.57	81 : 100	s.	s. CH₃OH	an. 146	d.	17
	v.s.	s.	s.	77.5—78	222.5—223.5	18
		s. C₆H₆	s. ligroin.	38	145—146/13	19
	h.s.s.	s.s.	v.s.	123—124		20
	m.		m.	40	259	21
0.9734/22°	1 : 4/15°				87.5—88	22
1.064/15°	s.s.			liq.	d. 200—205	23
				62—64		24
	h.s.	s.s.	s.	121		25
	s.	s.	s.	<100		26
	c.s.s. ; h.s.	s.		191		27
					278	28
		s.		88—89		29

	Name	Formula.	Formula Weight.	Empirical Formula.
1	Diacetyl *m*-toluylene diamine, 1:2:4	$CH_3.C_6H_3:(NH.CO.CH_3)_2$	206.18	$C_{11}H_{14}O_2N_2$
2	Diacetylene	$CH : C.C : CH$	50.04	C_4H_2
3	Diallyl	$(C_3H_5)_2$	82.11	C_6H_{10}
4	Dialuric acid	$C_4H_4N_2O_4$	144.07	$C_4H_4O_4N_2$
5	Diamino-anthraquinone, 1:4	$C_{14}H_6O_2(NH_2)_2$	238.17	$C_{14}H_{10}O_2N_2$
6	— —, 1:5	,, ,,	238.17	,,
7	— —, 1:8	,, ,,	238.17	,,
8	— benzoic acid, COOH:NH₂:NH₂=1:2:3	$C_6H_3(NH_2)_2COOH$	152.12	$C_7H_8O_2N_2$
9	1:3:4	,, ,,	152.12	,,
10	1:3:5	,, ,, $.H_2O$	170.14	,,
11	— benzophenone, 2:2′	$(C_6H_4NH)_2CO$	210.17	$C_{13}H_{10}ON_2$
12	— —, 4:4′	,, ,,	210.17	,,
13	— diphenylamine, 4:4′	$(C_6H_4.NH_2)_2NH$	199.19	$C_{12}H_{13}N_3$
14	— diphenylmethane	$(C_6H_4.NH_2)_2CH_2$, 4:4′	198.20	$C_{13}H_{14}N_2$
15	— stilbene	$(C_6H_4.NH_2)_2C_2H_2$	210.20	$C_{14}H_{14}N_2$
16	— triphenylmethane	$C_6H_5.CH(C_6H_4.NH_2)_2$, 4:4′	274.26	$C_{19}H_{18}N_2$
17	Dianisidine	$C_{12}H_6(OCH_3)_2(NH_2)_2$	244.22	$C_{14}H_{16}O_2N_2$
18	Diazo-acetic ester	$(COOC_2H_5)CHN$	114.09	$C_4H_6O_2N$
19	— amino-benzene	$C_6H_5.N_2.NH.C_6H_5$	197.18	$C_{12}H_{11}N_3$
20	— — naphthalene	$C_{10}H_7.N_2.NH.C_{10}H_7$	297.25	$C_{20}H_{15}N_3$
21	— benzene chloride	$C_6H_5.N_2.Cl$	140.55	$C_6H_5N_2Cl$
22	— — cyanide	$C_6H_5.N_2.CN.HCN$	158.13	$C_8H_6N_4$
23	— — imide	$C_6H_5.N\overset{N}{\underset{N}{\shortmid\shortmid}}$	119.10	$C_6H_5N_3$
24	— — nitrate	$C_6H_5.N_2.NO_3$	167.10	$C_6H_5O_3N_3$
25	— — sulphonic acid, *m*	$C_6H_4\overset{N_2}{\underset{SO_3}{\shortmid}}$	184.14	$C_6H_4O_3N_2S$
26	— — — —, *p*	,,	184.14	,,
27	— methane	CH_2N_2	42.04	CH_2N_2
28	Dibenzoyl catechol	$C_6H_4:(O.CO.C_6H_5)_2$	318.21	$C_{20}H_{14}O_4$
29	— hydroquinone	,, ,,	318.21	,,
30	— *m*-phenylene diamine	$C_6H_4:(NH.CO.C_6H_5)_2$	316.24	$C_{20}H_{16}O_2N_2$
31	— resorcinol	$C_6H_4:(O.CO.C_6H_5)_2$	318.21	$C_{20}H_{14}O_4$

Density H₂O=1.	Solubility in Water	Alcohol	Ether	M.P. °C	B.P. °C	
				224		1
				gas		2
0.6895/20°	i.			liq.	59—59.6/744	3
	s.s.					4
	v.s.s.	s.	s., s. C₆H₆	268	subl.	5
	s.s.	s.	s.	319		6
	i.	s.		262		7
	s.s.			190—191 d		8
	h.s.			d. 210—211		9
	h.s.	v.s.	v.s.	an. 236	d	10
	h.s.	s.	s.	172		11
	h.s.	s.	s.	239	d. 250	12
	s.s.		s.	158	d.	13
	v.s.	v.s.	s. C₆H₆	88—89		14
	s.s.	s.		227—228	subl. d.	15
	v.s.s.	s.	s.	139		16
	h.s.s.	h.s.	s.s., s. C₆H₆	135		17
1.083/24°	s.s.	m.	m.		140—141 d.	18
	i.	h.s.	v.s.	96	expl.	19
			s.	expl. 174		20
	s.	s.s.				21
	s.s.			70		22
1.124/0°	i.	s.s.	s.s.	oil	73.5/22—24	23
1.37	v.s.	s.s.	v.s.s.	expl.		24
	s., d. 60°			d.		25
	c.i., 60° s., h.d.					26
			s.		gas	27
	i.	s.s.	s.s.	84		28
		h.v.s.		199		29
		v.s.		240		30
		v.s.		117		31

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Dibenzoyl succinic acid, diethyl ester	$C_2H_2(CO.C_6H_5)_2(COOC_2H_5)_2$	382.29	$C_{22}H_{22}O_6$
2	— m-toluylene diamine 1:2:4	$CH_3.C_6H_3:(NH.CO.C_6H_5)_2$	330.26	$C_{21}H_{18}O_2N_2$
3	Dibenzyl	$C_6H_5.CH_2.CH_2.C_6H_5$	182.18	$C_{14}H_{14}$
4	— amine	$(C_6H_5.CH_2)_2:NH$	197.20	$C_{14}H_{15}N$
5	— ether, see	Benzyl ether		
6	— ketone	$(C_6H_5.CH_2)_2:CO$	210.19	$C_{15}H_{14}O$
7	Dibenzylidine acetone	$(C_6H_5.CH:CH)_2CO$	234.20	$C_{17}H_{14}O$
8	Dibromo anthracene	$C_6H_4:C_2Br_2:C_6H_4, 9:10$	335.97	$C_{14}H_8Br_2$
9	— anthraquinone, 1:2	$C_6H_4:(CO)_2:C_6H_3Br_2$	366.90	$C_{14}H_6O_2Br_2$
10	——, 2:6	$C_6H_3Br:(CO)_2:C_6H_3Br$	366.90	,,
11	——, 2:7	,, ,,	366.90	,,
12	— benzene, o	$C_6H_4Br_2$	235.90	$C_6H_4Br_2$
13	——, m	,,	235.90	,,
14	——, p	,,	235.90	,,
15	— ethane, asym.	$CH_3.CHBr_2$	187.88	$C_2H_4Br_2$
16	— succinic acid	$C_2H_2Br_2(COOH)_2$	275.89	$C_4H_4O_4Br_2$
17	Dichlor acetal	$CHCl_2.CH:(OC_2H_5)_2$	187.05	$C_6H_{12}O_2Cl_2$
18	— acetaldehyde	$CHCl_2.CHO$	112.95	$C_2H_2OCl_2$
19	— acetamide	$CHCl_2.CONH_2$	127.96	$C_2H_3ONCl_2$
20	— acetic acid	$CHCl_2.COOH$	128.95	$C_2H_3O_2Cl_2$
21	— acetate, ethyl	$CHCl_2.COOC_2H_5$	156.99	$C_4H_6O_2Cl_2$
22	— acetone	$CHCl_2.CO.CH_3$	126.97	$C_3H_4OCl_2$
23	— acetyl-chloride	$CHCl_2.COCl$	147.40	C_2HOCl_3
24	— aniline, 1:2:4	$C_6H_3Cl_2.NH_2$	162.00	$C_6H_5NCl_2$
25	——, 1:2:5	,,	162.00	,,
26	——, 1:3:5	,,	162.00	,,
27	——, 1:3:4	,,	162.00	,,
28	— anthracene, 9:10	$C_{14}H_8Cl_2$	247.05	$C_{14}H_8Cl_2$
29	— anthraquinone, 1:2	$C_{14}H_6O_2:Cl_2$	277.04	$C_{14}H_6O_2Cl_2$
30	——, 1:4	,, ,,	277.04	,,
31	——, 1:5	,, ,,	277.04	,,
32	——, 1:8	,, ,,	277.04	,,
33	——, 2:6	,, ,,	277.04	,,
34	——, 2:7	,, ,,	277.04	,,
35	— benzene, o	$C_6H_4Cl_2$	146.98	$C_6H_4Cl_2$
36	——, m	,,	146.98	,,
37	——, p	,,	146.98	,,

Density $H_2O=1$.	Water.	Solubility in Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.244/20°		1 : 200	v.s.s.			1
			v.s.	224		2
0.9416/80.6°	s. CS_2	s.s.	s.	52	284	3
1.033/14°	s. CS_2	s.	s.	liq.	300	4
						5
			s.s.	33	331	6
	s. acetone	s.s.	s.s.	112—113		7
	s.h. C_6H_6	v.s.s.	s.s.	220—221	subl.	8
		s.s.	s. C_6H_6	265		9
		v.s.s.	s. C_6H_6	289—290		10
				323		11
1.977/18°		s.	s. C_6H_6	5.6	223.8/751	12
1.955/19°		s.		1—2	219.4/758.4	13
2.261 cryst.		s.	s.	87.2	219	14
2.100/17.5°					112.5	15
	h.s.	s.	s.	255—256		16
1.1383/14°	s.s.			liq.	183—184	17
	i.			liq.	88—90	18
				97—98	233—234/745	19
1.5216/15°				-4	189—191	20
1.282/20°				liq.	156—157	21
1.236/21°	s.s.			liq.	120	22
					108—111	23
		s.		63	245	24
		s.		50	251	25
		s.		50.5	259—260	26
		s.		71	272	27
	s. C_6H_6	s.s.	s.s.	209		28
				261		29
				187.5—188		30
	s.			248—251		31
	s.			199		32
				280—282		33
				208—210		34
1.3278/0°		s.	s.s.	-14	179	35
1.3047/0°		s.		-18	172	36
1.526/21.5°	s. C_6H_6	h.m.	v.s.	53	172	37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Dichlor benzoic acid, 1:3:4	$C_6H_3Cl_2.COOH$	190.99	$C_7H_4O_2Cl_2$
2	— —, 1:2:5	,, ,,	190.99	,,
3	— diphenyl, p	$C_6H_4Cl.C_6H_4Cl$	234.04	$C_{12}H_8Cl_2$
4	— ethane, $asym.$	$CH_3.CHCl_2$	98.96	$C_2H_4Cl_2$
5	— ether	$CH_2Cl.CHCl.O.C_2H_5$	143.00	$C_4H_8OCl_2$
6	— ethylene, asym.	$CH_2:CCl_2$	96.95	$C_2H_2Cl_2$
7	— —, sym.	$CHCl:CHCl$	96.95	,,
8	— hydrin, $\alpha\gamma$	$CH_2Cl.CHOH.CH_2Cl$	128.98	$C_3H_6OCl_2$
9	— —, $\beta\gamma$	$CH_2Cl.CHCl.CH_2OH$	128.98	,,
10	— —, $\alpha\alpha$	$CH_3.CHOH.CHCl_2$	128.98	,,
11	— naphthalene, 1:2	$C_{10}H_6Cl_2$	197.02	$C_{10}H_6Cl_2$
12	— —, 1:3	,,	197.02	,,
13	— —, 1:4	..	197.02	,,
14	— —, 1:5	..	197.02	,,
15	— —, 1:6	,,	197.02	,,
16	— —, 1:7	,,	197.02	,,
17	— —, 1:8	,,	197.02	,,
18	— —, 2:3	$C_{10}H_6Cl_2$	197.02	$C_{10}H_6Cl_2$
19	— —, 2:6	,,	197.02	,,
20	— —, 2:7	,,	197.02	,,
21	— nitro benzene, $NO_2:Cl_2=1:2:3$	$Cl_2:C_6H_3.NO_2$	191.98	$C_6H_3O_2NCl_2$
22	— — —, 1:2:4	,, ,,	191.98	,,
23	— — —, 1:2:5	,, ,,	191.98	,,
24	— — —, 1:3:4	,, ,,	191.98	,,
25	— — —, 1:3:5	,, ,,	191.98	,,
26	— m phenylene diamine, 2:5	$C_6H_2Cl_2(NH_2)_2$	177.02	$C_6H_6N_2Cl_2$
27	— phthalic acid, 3:6	$Cl_2:C_6H_2:(COOH)_2$	234.99	$C_8H_4O_4Cl_2$
28	— — anhydride, 3:6	$Cl_2:C_6H_2:(CO)_2:O$	216.98	$C_8H_2O_3Cl_2$
29	— quinoline, 2:3	$C_9H_5NCl_2$	198.02	$C_9H_5NCl_2$
30	— —, 2:4	,,	198.02	,,
31	— —, 2:6	,,	198.02	,,
32	— —, 2:7	,,	198.02	,,
33	— —, 5:6	,,	198.02	,,
34	— —, 5:7	,,	198.02	,,
35	— —, 5:8	,,	198.02	,,
36	— —, 6:8	,,	198.02	,,

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	s.s.	s.		201—202		1
	1 : 1193/11°	s.		156	301	2
				148	315	3
1.1743/20°				— 96.7	57.5/751mm.	4
1.174/23°					140—145	5
1.250/15°				37		6
					55	7
	1 : 6/72°			liq.	174—175	8
1.3799/0°				liq.	183	9
					146—149	10
		s.		34—35	280—282	11
				61	289	12
		s.		67—68	286—287/740	13
		s.		107	subl.	14
				48		15
		v.s.		62	286	16
				83		17
		o.v.s.	s.	120		18
		v.s.	s.	135	285	19
		h.s.		114—115		20
				61—62	257—258	21
1.669/22°		c.s.s.	s.C₆H₆	33	258.5	22
				55	266	23
				43	255—256	24
				65.4		25
				99—100		26
	h.s.s.	s.s.	s.s.	163 d.		27
				187	339	28
	v.s. C₆H₆	v.s.	v.s.	104—105		29
				67	280—282	30
				156		31
				98—99		32
				85		33
				116—117		34
		s.	s.	92—93		35
		s.		103—104		36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Dichlor quinone, 2 : 6	$C_6H_2O_2Cl_2$	176.97	$C_6H_2O_2Cl_2$
2	— —, 2 : 3	,,	176.97	,,
3	— —, 2 : 5	,,	176.97	,,
4	— stilbene	$C_{14}H_{10}Cl_2$	249.07	$C_{14}H_{10}Cl_2$
5	Dicyan diamide	$HN:C(NH_2).NH.CN$	84.08	$C_2H_4N_4$
6	— diamidine	$HN:C(NH_2).NH.CO.NH_2$	102.10	$C_2H_6ON_4$
7	Diethyl acetic acid	$(C_2H_5)_2:CH.COOH$	116.13	$C_6H_{12}O_2$
8	— acetoacetic acid, ethyl ester	$CH_3CO.C:(C_2H_5)_2(COOC_2H_5)$	186.19	$C_{10}H_{18}O_3$
9	— amine	$(C_2H_5)_2:NH$	73.12	$C_4H_{11}N$
10	— amino phenol, p.	$(C_2H_5)_2N.C_6H_4OH$	165.18	$C_{10}H_{15}ON$
11	— aniline	$C_6H_5.N:(C_2H_5)_2$	149.18	$C_{10}H_{15}N$
12	— benzene, p	$C_6H_4:(C_2H_5)_2$	134.16	$C_{10}H_{14}$
13	— cyanamide	$CN:(C_2H_5)_2$	98.12	$C_5H_{10}N_2$
14	— glycollic acid	$(C_2H_5)_2:C(OH)COOH$	132.13	$C_6H_{12}O_3$
15	— ketone	$(C_2H_5)_2:CO$	86 11	$C_5H_{10}O$
16	— malonic acid	$(C_2H_5)_2C:(COOH)_2$	160.13	$C_7H_{12}O_4$
17	— oxamic acid, ethyl ester	$CON(C_2H_5)_2.COOC_2H_5$	173.17	$C_8H_{15}O_3N$
18	— phosphine	$(C_2H_5)_2:PH$	90.15	$C_4H_{11}P$
19	— phosphoric acid	$PO(OC_2H_5)_2OH$	154.15	$C_4H_{11}O_4P$
20	— sulphate, see	Ethyl sulphate		
21	— urea, α	$CO:(NH.C_2H_5)_2$	116.14	$C_5H_{12}ON_2$
22	— —, β	$NH_2.CO.N:(C_2H_5)_2$	116.14	,,
23	Diethylene diamine, (piperazine)	$NH:(C_2H_4)_2:NH$	86.12	$C_4H_{10}N_2$
24	— glycol	$CH_2OH.CH_2.O.CH_2$ CH_2OH	106.10	$C_4H_{10}O_3$
25	Digallic acid, α	$(OH)_3C_6H_2.COO.C_6H_2(OH)_2$ $COOH$	322.15	$C_{14}H_{10}O_9$
26	Diglycerol	$C_6H_{14}O_5$	166.14	$C_6H_{14}O_5$
27	Diglycollamide acid	$NH:(CH_2.COOH)_2$	133.09	$C_4H_7O_4N$
28	Diglycollic acid	$O:(CH_2.COOH)_2$	134.07	$C_4H_6O_5$
29	Dihydro acrylic acid	$C_3H_6O_2$	126.08	$C_6H_6O_3$
30	— benzene, 1 : 2	$C_6H_6.H_2$	80.09	C_6H_8
31	— carveol, α	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
32	— carvone	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
33	— cymene	$C_{10}H_{14}.H_2$	136.18	$C_{10}H_{16}$
34	— naphthalene, 1 : 4	$C_{10}H_8.H_2$	130.13	$C_{10}H_{10}$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C	B.P. °C	
	h.s.s.	h.v.s.	s. OHCl₃	120		1
				96		2
				161		3
	s.	s.	s.	170		4
	s.	s.	s. ao.	204	d.	5
				105		6
0.9355/0°					151—152	7
0.9743/15°					218	8
0.7116/15°	v.s.	s.		− 40	55.5/759mm.	9
				74	276—280	10
0.939/18°	i.	s.	s.	− 38.8	215.5	11
0.8622/18°	i.	s.	s.	liq.	182—183	12
				liq.	186	13
	1 : 2.8			80	subl. 50	14
0.8175/16.6°	1 : 24				102.7	15
	65 :100/16°	s.s.	s.s.	121		16
					260	17
$> H_2O$				85		18
	v.s.	c.v.s.				19
						20
1.0415	s.	s. —	s.	112—113	263	21
		v.s.	v.s.	74		22
	v.s.	v.s.		104	145—146	23
1.132/0°	s.	s.	s.		250	24
	s.	s.	i.		282 d.	25
	h.v.s.		i.		220—230/10	26
	1 : 41/5°	i.	i.	247.5		27
	s.	s.	s.	148	d.	28
	s.	s.			97/35mm.	29
					80.5	30
0.927/20°				liq.	221	31
0.928/19°				liq.	221/758mm.	32
					174	33
				15.5	212	34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Dihydro phthalic acid, 1 : 4 : 2 : 3	$(H_2):C_6H_4:(COOH)_2$	136.10	$C_8H_8O_4$
2				
3	———, *tere.*	,, ,,	136.10	,,
4	— quinoline	C_9H_9N	131.13	C_9H_9N
5	— resorcinol	$C_6H_6O_2.H_2$	112.09	$C_6H_8O_2$
6	Dihydroxy acetone	$(OH_2.OH)_2:CO$	90.06	$C_3H_6O_3$
7	— anthracene, 1 : 8, chrysazol	$C_{14}H_8(OH)_2$	210.15	$C_{14}H_{10}O_2$
8	——, 1 : 5, rufol	,,	210.15	,,
9	— anthroquinones :	$C_{14}H_6O_2:(OH)_2$	240.13	$C_{14}H_8O_4$
10	1 : 2, Alizarin	,, ,,	240.13	,,
11	1 : 3, Purpuroxanthene, Xanthopurpurin	,, ,,	240.13	,,
12	1 : 4, Quinizarin	,, ,,	240.13	,,
13	1 : 5, Anthrarufin	,, ,,	240.13	,,
14	1 : 6,	,, ,,	240.13	,,
15	1 : 7,	,, ,,	240.13	,,
16	1 : 8, Chyrsazin	,, ,,	240.13	,,
17	2 : 3, Hystazarin	,, ,,	240.13	,,
18	2 : 6, Anthraflavic acid	,, ,,	240.13	,,
19	2 : 7, *iso*-Anthraflavic acid	,, ,,	240.13	,,
20	— benzene, *o*, pyrocatechol	$C_6H_4(OH)_2$	110.08	$C_6H_6O_2$
21	——, *m*, resorcinol	,,	110.08	,,
22	——, *p*, hydroquinone	,,	110.08	,,
23	— benzoic acid, hydroxy salicylic protocatechoic	$(OH)_2:C_6H_3.COOH$ 2 : 5 : 1 3 : 4 : 1 3 : 4 : 1	154.08 154.08 154.08	$C_7H_6O_4$,, ,,
24	— benzophenone, 2 : 4′	$(C_6H_4OH)_2:CO$	214.15	$C_{13}H_{10}O_3$
25	——, 4 : 4′.	,, ,,	214.15	,,
26	——, 3 : 3′	,, ,,	214.15	,,
27	——, benzoyl pyrocatechol	$C_6H_5.CO.C_6H_3(OH)_2.\frac{1}{2}H_2O$	236.16	,,
28	——, benz. resorcinol	,,	214.15	,,
29	— cinnamic acid, 1 : 3 : 4	$(OH)_2:C_6H_3.C_2H_2.COOH$ $\frac{1}{2}H_2O$	189.12	$C_9H_8O_4$
30	— diphenylmethane	$(C_6H_4OH)_2:CH_2, 4 : 4′.$	200.16	$C_{13}H_{12}O_2$

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	1 : 100 c.	s.	s.s	153		1
						2
	i.					3
				220—226		4
	v.s.	v.s.	v.s.s	104—106		5
	v.s.	h.s.	v.s.s.	68—75		6
		s.	s. alk.	d. 225		7
		s.	s. alk.	d. 265		8
						9
	0.034 : 100/100°	s.s.	s.s. ; s.CS_2	289—290	420	10
		s.s.		262—263		11
		s.s.	s.	194—195		12
	i.	v.s.	s.	280		13
				269		14
		s.s.	s.	291—293		15
		s.	s.	190—192		16
		h.s.	h.s.	>280		17
	i.	..	i.	>330		18
		s.	i.	>330		19
						20
1.375/15°	s.	s.	s.	105,5	245	21
1.283	86.4 : 100/0°	s.	s.	111.6	276.5	22
1.326/15°	5.85 : 100/15°	s.	s.	170.3	285	23
	h.s.	s.	s.	196	d.	
1.542/4°	1 : 54/14°	v.s.	s.	200	d.	
	h.s.	s.	s.	232—233		
	h.s.s.	h.s.	s.	144		24
	h.s.	s.	s.	210		25
	s.	s.		162—163		26
	h.s.	s.	s. alk.	an. 145		27
	h.s.	s.	s.	144		28
	v.s.	v.s.	v.s.	d. 124		29
		s.	s.	158	subl	30

Name.	Formula.	Formula Weight.	Empirical Formula.
Dihydroxy naphthalene, 1:4	$C_{10}H_6(OH)_2$	160.11	$C_{10}H_8O_2$
2 ——, 1:2	,,	160.11	,,
3 ——, 1:5	,,	160.11	,,
4 ——, 1:8	,,	160.11	,,
5 ——, 2:3	,,	160.11	,,
6 ——, 2:6	,,	160.11	,,
7 ——, 2:7	,,	160.11	,,
8 — quinone, 2:5	$C_6H_2O_2(OH)_2$	140.06	$C_6H_4O_4$
9 — stearic acid, α β	$C_{18}H_{34}O_2(OH)_2$	316.28	$C_{18}H_{36}O_4$
10 — tartaric acid	$[C(OH)_2COOH]_2$	182.07	$C_4H_6O_8$
11 — terephthalic acid, 2:5	$C_6H_2(OH)_2(COOH)_2.2H_2O$	234.12	$C_8H_{10}O_6$
12 — toluene, homopyro-catechol, 1:3:4	$CH_3.C_6H_3:(OH)_2$	124.10	$C_7H_8O_2$
orcinol, 1:3:5	,, ,, .H_2O	142.08	,,
iso-orcinol, β	,, ,,	124.10	,,
cresorcinol, 1:2:4	,, ,,	124.10	,,
hydrotoluquinone, 1:2:5	,, ,,	124.10	,,
13 — xylene, 4:6:1:3	$C_6H_2(CH_3)_2(OH)_2$	138.12	$C_8H_{10}O_2$
14 ——, 2:5:1:4	,, ,,	138.12	,,
15 ——, 2:6:1:4	,, ,,	138.12	,,
16 Di-iodo benzene, o	$C_6H_4I_2$	329.90	$C_6H_4I_2$
17 ———, m	,,	329.90	,,
18 ———, p	,,	329.90	,,
19 Di-iso butylamine	$(C_4H_9)_2:NH$	129.20	$C_8H_{19}N$
20 —— butylene	$(CH_3)_2:C:CH.C(CH_3)_3$	112.17	C_8H_{16}
21 —— butyl ketone	$C_4H_9.CO.C_4H_9$	142.19	$C_9H_{18}O$
22 —— propyl ketone	$C_3H_7.CO.C_3H_7$	114.15	$C_7H_{14}O$
23 Dimethyl acetoacetic acid, ethyl ester	$CH_3CO.C(CH_3)_2COOC_2H_5$	158.15	$C_8H_{14}O_3$
24 ———, methyl ester	$CH_3CO.C(CH_3)_2COOCH_3$	144.13	$C_7H_{12}O_3$
25 — amine	$(CH_3)_2:NH$	45.08	C_2H_7N
26 — amino azo benzene	$(CH_3)_2:N.C_6H_4.N_2.C_6H_4$	215.13	$C_{14}H_{15}N_3$
27 — aniline	$C_6H_5.N:(CH_3)_2$	121.14	$C_8H_{11}N$
28 — anthracene, 1:6	$C_{14}H_8:(CH_3)_2$	206.19	$C_{16}H_{14}$
29 ——, 1:8	,, ,,	206.19	,,
30 ——, 2:6	,, ,,	206.19	,,
31 ——, 2:7	,, ,,	206.19	,,

Density (0)=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	h.s.	h.s.	s.	173		1
	s.s.		s. alk.	60		2
	h.s.	s	s.	250		3
	h.s.s.	s. C_6H_6	s.	140		4
	h.s.s.	s.	s.	159		5
	c.s.s.	s.	s.	215—216	subl.	6
	h.s.	s.s.	s. C_6H_6	190	subl.	7
	c.s.s.	v.s.	s.s.		sub. 215—220 & d.	8
		0.6 : 100	0.2 : 100	126		9
	v.s.	/19°	/18°	98 d		10
	h.s.	s.s.	s.s.	d.		11
	v.s.	v.s.	v.s.	65	251	12
1 29	s.	s.	s.	58, an. 107	287—290	
	s.	s.	s.	87	260	
	v.s.	v.s.	v.s.	103—104	267—270	
	v.s.	v.s.	v.s.	126—126.5	subl.	
	v.s.	v.s.	v.s.	124.5—125	276—279	13
	h.s.	v.s.	v.s.	217	subl.	14
	s.	s.	—	163	277-280	15
		s.		27	286.5/751	16
		s.		40.4	284.7/756.5	17
		s.		128	285	18
	v.s.s.			139—140		19
0.734/0°					102.5/756	20
0.833/20°	i.			liq.	164—166/741	21
0.8062/20°				liq.	125—126	22
0.9813/15*					184.1—184.2/ 755.8mm.	23
1.0118/15°					172—173/754mm	24
0.6865/—5.8°	s	s.		liq.	7.3	25
					117	26
0.9555/20°		s.		2.5	193.1	27
	i.	s.		240		28
	i.	s.		86		29
	i.	s.		231—232		30
	i.	s.		243—244		31

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Dimethyl ethyl benzene, 1:3:5	$C_6H_3(CH_3)_2C_2H_5$	134.16	$C_{10}H_{14}$
2 — furane, 2:5	$C_4H_2O(CH_3)_2$	96.09	C_6H_8O
3 — glyoxime	$CH_3.C:(NOH).C:(NOH).CH_3$	116.10	$C_4H_8O_2N_2$
4 — hydro quinone	$C_6H_4(OCH_3)_2$	138.12	$C_8H_{10}O_2$
5 — hypophosphorous acid	$(CH_3)_2OH.PO$	94.11	$C_2H_7O_2P$
6 — malonic acid	$(CH_3)_2:C:(COOH)_2$	132.09	$C_5H_8O_4$
7 — — anhydride	$(CH_3)_2:C:(CO)_2:O$	114.07	$C_5H_6O_3$
8 — naphthalene, 1:4	$C_{10}H_6(CH_3)_2$	156.16	$C_{12}H_{12}$
9 — —, 2:6	,,	156.16	,,
10 — naphthylamine, a	$C_{10}H_7.N(CH_3)_2$	171.17	$C_{12}H_{13}N$
11 — —, β	,, ,,	171.17	,,
12 — nitrosamine	$(CH_3)_2:N.NO$	74.08	$C_2H_6ON_2$
13 — phosphine	$(CH_3)_2:PH$	62.11	C_2H_7P
14 — pyrazine	$CH \begin{array}{c} C(CH_3).N \\ N:C(CH_3) \end{array} CH$	108.11	$C_6H_8N_2$
15 — pyridine, see	Lutidine		
16 — pyrrole, 2:5	$C_4H_2N(CH_3)_2$	95.11	C_6H_9N
17 — resorcinol	$C_6H_4(OCH_3)_2$	138.12	$C_8H_{10}O_2$
18 — sulphate	$SO_2(OCH_3)_2$	126.12	$C_2H_6O_4S$
19 — thetine	$CH_2.S(SCH_3)_2$ $\ \dot{C}O.O$	120.14	$C_4H_8O_2S$
20 — thiophene, 2:3	$C_4H_2S(CH_3)_2$	112.15	C_6H_8S
21 — —, 2:4	,, ,,	112.15	,,
22 — toluidine, o	$(CH_3)_2.N.C_6H_4.CH_3$	135.16	$C_9H_{13}N$
23 — —, m	,, ,,	135.16	,,
24 — —, p	,, ,,	135.16	,,
25 — urea, $sym.$	$CO:(NH.CH_3)_2$	88.10	$C_3H_8ON_2$
26 — —, $asym.$	$(CH_3)_2.N.CO.NH_2$	88.10	,,
27 Dinaphthol, a	$OH.C_{10}H_6.C_{10}H_6.OH$	286.21	$C_{20}H_{14}O_2$
28 —, β	,, ,,	286.21	,,
29 Dinaphthyl	$(C_{10}H_7)_2$	254.21	$C_{20}H_{14}$
30 — amine, 2:2'	$(C_{10}H_7)_2:NH$	269.23	$C_{20}H_{15}N$
31 — ether, 1:1'	$(C_{10}H_7)_2:O$	270.21	$C_{20}H_{14}O$
32 — —, 1:2'	,, ,,	270.21	,,
33 — —, 2:2'	,, ,,	270.21	,,

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.861/20°				−20	185	1
0.9026/17.7°	i.	m.	s.	liq.	93	2
					243	3
	i.		s. C_6H_6	55—56	205	4
	s.	s.	s.	76		5
	1 : 10/13°	v.s.	s.s.	184—184.5		6
				140	d. 170—175	7
1.0176/20°					262—264/751mm.	8
				110—111		9
1.0423/20°	i.	s.	s.	liq.	274—275/711	10
		s.		46—47.7	305	11
					148.5/724	12
$<H_2O$	i.			liq.	25	13
0.9896/18°	m.	m.	m.	15	155	14
						15
0.9353/19.8°	v.s.s.	v.s.	v.s.	oil	165/752mm.	16
1.0803/0°	v.s.s.	s.	s.	−17	214—215	17
1.3276/20°				liq.	188.3—188.6	18
	del.	s.		d.		19
0.9938/21°				liq.	136—137	20
0.9956/20°					137—138	21
0.9333/15°					183	22
					215	23
0.9424/15°					211—211.5	24
				100.5	268—273 (corr.)	25
		s.s.	v.s.s.	182—185		26
	i.	s.	s.	300		27
	i.	s.	s.			28
			s.	180—182	subl.	29
	i.	s.s.	s. C_6H_6	170.5	471	30
	i.	h.s.	v.s.	109—110		31
				81	264/15mm.	32
				105	250/19mm.	33

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Dimethyl ketone, 1:2'	$(C_{10}H_7)_2:CO$	282.22	$C_{21}H_{14}O$
2 ——, 2:2' α isomer	,, ,,	282.22	,,
3 ——, 2:2' β isomer	,, ,,	282.22	,,
4 — methane, α	$(C_{10}H_7)_2:CH_2$	268.23	$C_{21}H_{16}$
5 ——, β	,, ,,	268.23	,,
6 Dinicotinic acid, see	Pyridine carboxylic acid		
7 Dinitro aniline, 1:2:4	$C_6H_3(NO_2)_2NH_2$	183.10	$C_6H_5O_4N_3$
8 ——, 1:2:6	,, ,,	183.10	,,
9 — anisole, 1:3:5	$(NO_2)_2:C_6H_3.OCH_3$	198.10	$C_7H_6O_5N_2$
10 — anthraquinone, 1:8	$C_{14}H_6O_2(NO_2)_2$	298.14	$C_{14}H_6O_6N_2$
11 ——, 2:7	,, ,,	298.14	,,
12 — benzene, o	$C_6H_4(NO_2)_2$	168.08	$C_6H_4O_4N_2$
13 ——, m	,, ,,	168.08	,,
14 ——, p	,, ,,	168.08	,,
15 — benzoic acid, 1:2:5	$C_6H_3.COOH(NO_2)_2$	212.09	$C_7H_4O_6N_2$
16 ——, 1:2:4	,, ,,	212.09	,,
17 ——, 1:2:6	,, ,,	212.09	,,
18 ——, 1:3:4	,, ,,	212.09	,,
19 ——, 1:3:5	,, ,,	212.09	,,
20 — p cresol	$C_6H_2(NO_2)_2(CH_3)OH$	198.10	$C_7H_6O_5N_2$
21 — dichlor benzene, 1:3:2:5	$C_6H_2(NO_2)_2Cl_2$	236.99	$C_6H_2O_4N_2Cl_2$
22 — diphenyl, 4:4'	$NO_2.C_6H_4.C_6H_4.NO_2$	244.14	$C_{12}H_8O_4N_2$
23 ——, 2:2'	,, ,,	244.14	,,
24 — diphenylamine, 2:4	$(C_6H_4.NO_2)_2:NH$	259.16	$C_{12}H_9O_4N_3$
25 ——, 4:4'	,, ,,	259.16	,,
26 — 1:4 hydroxy benzoic acid, 3:5	$C_6H_2OH(COOH)(NO_2)_2$	228.09	$C_7H_4O_7N_2$
27 — methane	$CH_2(NO_2)_2$	106.04	$CH_2O_4N_2$
28 — naphthalene, 1:5	$C_{10}H_6(NO_2)_2$	218.12	$C_{10}H_6O_4N_2$
29 ——, 1:8	$C_{10}H_6(NO_2)_2$	218.12	$C_{10}H_6O_4N_2$
30 ——, 1:3	,, ,,	218.12	,,
31 — naphthol, 1:2:4	$C_{10}H_5OH(NO_2)_2$	234.12	$C_{10}H_6O_5N_2$
32 ——, 1:2:6	,, ,,	234.12	,,
33 — phenol, 1:3:4	$C_6H_3OH(NO_2)_2$	184.08	$C_6H_4O_5N_2$
34 ——, 1:2:3	,, ,,	184.08	,,

Density $H_2O=1.$	Water.	Solubility in—— Alcohol.	Ether.	M.P. °C.	B.P. °C.	
		1 : 77	s., s. C_6H_6	135		1
		1 : 267		125.5		2
	s. $CHCl_3$	1 : 1250	v.s.s.	164.5		3
	s. $CHCl_3$	h. 1 : 15	s., s. C_6H_6	109	>360	4
		s.	s. C_6H_6	93		5
						6
1.615/14°	h.v.s.s.	s.		181		7
		h.s.s.		138—139		8
				204		9
	v.s.s.	v.s.s.	v.s.s.	256—260	subl. d.	10
	s.h. acetic	s.s.	s.s.	280		11
1.565/17°	0.38 : 100 /100°	3.8 : 100 /25°		116.5	319/773.5	12
1.546/14°	i.	5.9 : 100 /24.6°		89.7	302.8	13
1.587/17°	0.18 : 100 /100°	h.s.		171—172	299/773mm.	14
	h.s.s.	v.s.	s. C_6H_6	177		15
1.672				180		16
1.681	h.v.s.			202	d.	17
1.674	0.673 :100/25°	s.s.	s.s.	163—164		18
	h.s.	s.	s.s.	206		19
				84		20
				104	312 d.	21
		c.s.s.		233		22
		h.s.		93.5		23
				153		24
		s.		214		25
				248.5—249.5		26
					d.	27
		s.s.	s. C_6H_6	216	subl.	28
	1 : 100, $CHCl_3$	s.s.	s.s. C_6H_6	170	d.	29
		s.		144	subl.	30
	h.v.s.s.	s.	s., s. acetic	143		31
	h.v.s.	v.s.	v.s.	195 d.		32
	h. 1 : 21	c.v.s.s.	s.	134		33
	s.s.	h.s.	s.	144		34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Dinitro phenol, 1:2:4	$C_6H_2OH(NO_2)_2$	184.08	,,
2	— —, 1:2:5	,, ,,	184.08	,,
3	— —, 1:2:6	,, ,,	184.08	,,
4	— resorcinol, 2:4	$C_6H_2(NO_2)_2(OH)_2$	200.08	$C_6H_4O_6N_2$
5	— salicylic acid, 3:5	$C_6H_2OH(COOH)(NO_2)_2.H_2O$	246.11	$C_7H_6O_7N_2$
6	— toluene, 1:2:4	$C_6H_3.(CH_3)(NO_2)_2$	182.10	$C_7H_6O_4N_2$
7	— —, 1:2:6	,, ,,	182.10	,,
8	— —, 1:3:4	,, ,,	182.10	,,
9	— —, 1:3:5	,, ,,	182.10	,,
10	— xylene, 1:3:4:6	$C_6H_2(CH_3)_2(NO_2)_2$	196.12	$C_8H_8O_4N_2$
11	— —, 1:4:2:6	,, ,,	196.12	,,
12	— —, 1:4:2:3	,, ,,	196.12	,,
13	Dioctyl, see	Hexadecane		
14	Dioxindole	$C_6H_4\diagdown\!\!\begin{array}{c}CH(OH)\\ NH\end{array}\!\!\diagup CO$	149.11	$C_8H_7O_2N$
15	Diphenic acid	$(C_6H_4.COOH)_2$	242.15	$C_{14}H_{10}O_4$
16	Diphenol, 3:3′	$OH.C_6H_4.C_6H_4.OH$	186.14	$C_{12}H_{10}O_2$
17	—, 2:2′	,, ,,	186.14	,,
18	— 4:4′	,, ,,	186.14	,,
19	Diphenyl	$(C_6H_5)_2$	154.14	$C_{12}H_{10}$
20	— acetamidine	$CH_3.C(:N.C_6H_5).NH.C_6H_5$	210.20	$C_{14}H_{14}N_2$
21	— acetic acid	$(C_6H_5)_2:CH.COOH$	212.17	$C_{14}H_{12}O_2$
22	— amine	$(C_6H_5)_2:NH$	169.16	$C_{12}H_{11}N$
23	— benzene, p	$C_6H_4(C_6H_5)_2$	230.20	$C_{18}H_{14}$
24	— carbonate	$(C_6H_5O)_2CO$	214.15	$C_{13}H_{10}O_3$
25	— carboxylic acid, o	$C_6H_5.C_6H_4.COOH$	198.15	$C_{13}H_{10}O_2$
26	— — —, p	,, ,,	198.15	,,
27	— diacetylene	$C_6H_5.C:C.C:C.C_6H_5$	202.16	$C_{16}H_{10}$
28	— dicarboxylic acid, 2:2″	$(C_6H_4)_2(COOH)_2$	242.15	$C_{14}H_{10}O_4$
29	— ethane, $\alpha\alpha$	$CH_3.CH:(C_6H_5)_2$	182.18	$C_{14}H_{14}$
30	— ether, see	Phenyl ether		
31	— ethylene diamine	$NC_2H_4(C_6H_5.NH)_2$	212.21	$C_{14}H_{16}N_2$
32	— formamidine	$C_6H_5N:CH.NH.C_6H_5$	196.18	$C_{13}H_{12}N_2$
33	— hydrazine	$(C_6H_5)_2:N.NH_2$	184.18	$C_{12}H_{12}N_2$
34	— methane	$(C_6H_5)_2:CH_2$	168.16	$C_{13}H_{12}$

Density H$_2$O=1.	Water.	Solubility in Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.683/24°				113—114		1
				105		2
1.724				63--64		3
		s.		142	subl.	4
	h v.s.	s	s.	an.172—173	subl.	5
	i.	s.s.	s.s. OS$_2$	70.2		6
1.539		s.		66		7
1.32	i.	s.s.	2.19 : 100, OS$_2$	69.5—71		8
	s.s.	c.s.	s.	88—91		9
		h.s.		93		10
		s.s.		124		11
		s.		90		12
						13
	c. 1 : 12, h. 1 : 6	c. 1 : 15, h. 1 : 10	s. alk.	180	d. 195	14
	h.s.	v.s.	v.s.	228—229	subl.	15
	h.s.	s.	s.	123.5		16
	v.s.s.	s.	s.	98	315/768mm.	17
	s.s.	s.	s.	272		18
1.165	c. 6.7 : 100	c. 10 : 100	s.	70.5	254.9	19
	m.	m.	m.	134		20
	h.s.	s.	s.	148	268—271	21
1.159	s.s.	56 : 100 /19.5°	s.	54	302	22
	h.s. C$_6$H$_6$	h.s.s.	s.	205	subl.	23
	i.	h.s.	s.	78	301—302	24
	h.s.s	h.s.		110--111		25
	h.v.s.s.	s.	s.	224	subl.	26
		s.	s.	88		27
	i.	i.	i.	228—229	d.	28
				oil	286	29
						30
	i.	s.	s.	65		31
	s.s.	s.	s. C$_6$H$_6$	138—139		32
	s.s.	s.	s.	127	220/50mm.	33
1.0126/11°	s. CHCl$_3$	s.	s.	27	260—261	34

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Diphenyl nitrosamine,	see Nitroso diphenylamine		
2 — sulphide	$(C_6H_5)_2S$	186.20	$C_{12}H_{10}S$
3 — sulphone	$(C_6H_5)_2SO_2$	218.20	$C_{12}H_{10}O_2S$
4 — thiocyanate, *iso.*	$C_{12}H_9N.CS$	211.21	$C_{13}H_9NS$
5 — thiourea, *sym.*, see	Thiocarbanilide		
6 — tolylmethane	$(C_6H_5)_2:CH.(C_6H_4.CH_3)$	258.24	$C_{20}H_{18}$
7 — urea, *asym.*	$NH_2.CO.N(C_6H_5)_2$	212.18	$C_{13}H_{12}ON_2$
8 — urea, *sym.*, see	Carbanilide		
9 Diphenylene oxide	$(C_6H_4)_2:O$	168.12	$C_{12}H_8O$
10 — ketone, see	Fluorenone		
11 Diphenylol, *p*	$C_6H_5.C_6H_4OH$	170.14	$C_{12}H_{10}O$
12 Dipicolinic acid, see	Pyridine carboxylic acid		
13 Dipropyl amine, *norm.*	$(C_3H_7)_2:NH$	101.16	$C_6H_{15}N$
14 — ketone, *norm.*, see	Butyrone		
15 Dipyridine	$C_{10}H_{10}N_2$	158.15	$C_{10}H_{10}N_2$
16 Dipyridyl, 4 : 4″	$C_5H_4N.C_5H_4N$	156.13	$C_{10}H_8N_2$
17 Diquinoline	$C_{18}H_{12}N_2$	258.22	$C_{18}H_{12}N_2$
18 Diquinonyl, 6 : 6′	$C_{18}H_{12}N_2$	256.21	$C_{18}H_{12}N_2$
19 —, 2 : 7′	,,	256.21	
20 Diresorcinol, 3 :5 :3′ :5′	$(OH)_2C_6H_3.C_6H_3(OH)_2.2H_2O$	254.17	$C_{12}H_{10}O_4$
21 Dithio carbamic acid	$NH_2.CS_2H$	93.16	CH_3NS_2
22 — glycerin, see	Glycerin mercaptan		
23 Ditolyl	$(C_6H_4.CH_3)_2$	182.18	$C_{14}H_{14}$
24 — amine	$(C_6H_4.CH_3)_2:NH$	197 20	$C_{14}H_{15}N$
25 Diurea	$CO\begin{array}{c}NH.NH\\ \diagup \diagdown\\ \diagdown \diagup\\ NH.NH\end{array}CO$	116.08	$C_2H_6O_2N_4$
26 Dodecane	$C_{12}H_{26}$	170.27	$C_{12}H_{26}$
27 Dodecylene	$C_{12}H_{24}$	168.25	$C_{12}H_{24}$
28 Dulcitol	$C_6H_8(OH)_6$	182.14	$C_6H_{14}O_6$
29 Durene, 1 : 2 : 4 : 5	$C_6H_2(CH_3)_4$	134.16	$C_{10}H_{14}$
30 Eicosane	$C_{20}H_{42}$	282.44	$C_{20}H_{42}$
31 Elæo-margaric acid	$C_{17}H_{30}O_2$	266.33	$C_{17}H_{30}O_2$
32 — stearic acid	,,	266.33	,,
33 Elaidic acid	$C_{17}H_{33}COOH$	282.36	$C_{18}H_{34}O_2$
34 Ellagic acid	$CO.O.C_6H(OH)_2.O$	338.15	$C_{14}H_6O_8$
35 Emodin	$O.\ C_6H(OH)_3.CO$ $C_{14}H_4O_2(CH_3)(OH)_3.H_2O$	288.18	$C_{15}H_{10}O_5$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
						1
1.12/0°	i.	s.	m.	liq.	296/765mm.	2
	h.s.s.	h.s.	s., s. C_6H_6	124.5	376.4/722	3
			v.s.	58		4
						5
	s. C_6H_6	s.s.s.	s.	59—59.5	>360	6
				187—188		7
						8
-	i.	v.s.	s.	85	287	9
						10
		v.s.	v.s.	161—162	305—308	11
						12
0.7430/15°	5 :100/19°		–		110—111	13
						14
	h.s.	s.	s.	108	subl.	15
	h.v.s.	v.s.	v.s.	111—112	304.8	16
	i.	h.s.	s.	114		17
		s.		178		18
	i.	h.s.	s.s.	192.5	subl.	19
	h.v.s.		s.	310		20
	v.s.	v.s.	v.s.			21
						22
0.9172/121°	h.s.	s.	s.	5—7	286	23
				liq.	312/727.5	24
	c.s.s.	h.s.s.		270		25
0.7584/15°				- 12	214	26
0.7620/15°				- 31	96/15mm.	27
1.466/15°	1 : 39/15°	s.s.		188.5	275—280	28
		s.	s.	79—80	190	29
0.777/37°				37	205/15mm.	30
		s.	v.s.s.	48		31
		s.	v.s.	71		32
		v.s.	s.	54		33
1.667/18°	h.v.s.s.	s.s.	i.	d.		34
	s.	s.	s. acetic.	256—257		35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Epibromhydrin, a	$CH_2.O.CH.CH_2Br$	136.98	C_3H_5OBr
2	Epichlorhydrin, a	$CH_2.O.CH.CH_2Cl$	92.52	C_3H_5OCl
3	—, β	$O.CH_2.CHCl.CH_2$	92.52	,,
4	Epicyanhydrin	C_3H_5OCN	83.07	C_4H_5ON
5	Epi-iodohydrin	C_3H_5OI	183.98	C_3H_5OI
6	Erucic acid	$C_{22}H_{42}O_2$	338.45	$C_{22}H_{42}O_2$
7	Erythrin	$C_4H_8O_4(C_8H_7O_3)_2.\frac{1}{2}H_2O$	431.28	$C_{20}H_{22}O_{10}$
8	Erythrite, $meso.$	$C_4H_6(OH)_4$	122.10	$C_4H_{10}O_4$
9	Ethane	C_2H_6	30.06	C_2H_6
10	Ether, see	Ethyl ether		
11	Ethenyl triethyl ether	$CH_3.C(OC_2H_5)_3$	162.18	$C_8H_{18}O_3$
12	— tricarboxylic acid	$C_5H_5(COOH)_3$	162.07	$C_8H_6O_6$
13	Ethyl acetamide	$CH_3.CO.NH.C_2H_5$	87.10	C_5H_9ON
14	— acetoacetic acid, ethyl ester	$CH_3.CO.CH(C_2H_5)COOC_2H_5$	158.15	$C_8H_{14}O_3$
15	— acetylene	$C_2H.C_2H_5$	54.07	C_4H_6
16	— alcohol	C_2H_5OH	46.06	C_2H_6O
17	— amine	$C_2H_5.NH_2$	45.08	C_2H_7N
18	— amino benzoic acid, m	$C_2H_5.NH.C_6H_4.COOH$	165.14	$C_9H_{11}O_2N$
19	— — phenol, p	$C_2H_5.NH.C_6H_4OH$	137.14	$C_8H_{11}ON$
20	— aniline	$C_6H_5.NH.C_2H_5$	121.14	$C_8H_{11}N$
21	— anthracene	$C_6H_4:C_2H(C_2H_5):C_6H_4$	206.19	$C_{16}H_{14}$
22	—, dihydro	$C_6H_4:C_2H_3(C_2H_5):C_6H_4$	208.21	$C_{16}H_{16}$
23	— benzene	$C_6H_5.C_2H_5$	106.12	C_8H_{10}
24	— benzoic acid, o	$C_2H_5.C_6H_4.COOH$	150.13	$C_9H_{10}O_2$
25	— — —, m	,,	,,	150.13	,,
26	— — —, p	,,	,,	150.13	,,
27	— benzyl aniline	$(C_2H_5)(C_7H_7):N.C_6H_5$	211.22	$C_{15}H_{17}N$
28	— borate	$(C_2H_5)_3BO_3$	146.0	$C_6H_{15}O_3B$
29	— bromide	C_2H_5Br	108.97	C_2H_5Br
30	— carbazole	$C_{12}H_8N.C_2H_5$	195.18	$C_{14}H_{13}N$
31	— carbonate	$CO(OC_2H_5)_2$	118.11	$C_5H_{10}O_3$
32	— carbostyril	$C_6H_4.C_2H(C_2H_5).NH.CO$	174.16	$C_{11}H_{11}ON$
33	— carbylamine	$C_2H_5.NC$	55.07	C_3H_5N
34	— chloride	C_2H_5Cl	64.51	C_2H_5Cl
35	— chloroformate	$Cl.COO.C_2H_5$	108.56	$C_3H_5O_2Cl$

Density H₂O=1.	Water.	Solubility in— Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.615/14°					138—140	1
1.2040/0°	i.			liq.	116.5/761	2
					132—134	3
	h.s.	s.		162		4
1.03/13°	i.				160—180	5
		v.s.		33—34	281/30mm.	6
	v.s.s.	s.	1 : 328	an. 145		7
1.452/17°	v.s.	s.s.	l.	120	330	8
	s.s.	s.		gas	− 89/735	9
						10
0.94/22°	h.d.			142		11
	s.	s.	s.	d. 159		12
			s. ac.		205	13
0.9834/16°	i.				195—196	14
				liq.	18	15
0.7937/15°	m.		m.	− 117.6	77.8/753	16
0.6994/8°	m.	m.	m.	− 85.2	16.55	17
	h.s.s.	m.	m.	112		18
	i.	v.s.	h.s. C_6H_6	70	330	19
0.9625/20°				− 80	205—207	20
	i.	s.		60—61		21
1.049/18°	i.	m.	m.	oil.	320—323 d.	22
0.8759/20°	i.	m.	m.	− 92.8	135.8/758	23
1.050/15°	h.s.	s.	s.	68	subl.	24
	s.	s.		47		25
	h.s.	s.	s.	112		26
	i.	s.s.	s.s.		285—286/710mm	27
0.887/0°				121		28
1.450/15°	s.s.	m.	m	− 116	38.4	29
		h.s.	v.s.	67—68		30
0.9762/20°	i.	s.		liq.	126.4	31
				168		32
0.7591/4°				liq.	78	33
0.921/0°	2 : 100	m.	m.	− 141.6	12.5	34
1.139/15°	d.			liq.	94	35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Ethyl crotonic acid	$CH_3.C_2H(C_2H_5)COOH$	114.11	$C_6H_{10}O_2$
2	— cyanate	$N : C.OC_2H_5$	71.07	C_3H_5ON
3	— —, *iso*	$CO : N.C_2H_5$	71.07	,,
4	— diphenylamine	$(C_6H_5)_2 : N.C_2H_5$	197.20	$C_{14}H_{15}N$
5	— diphenylphosphine	$(C_6H_5)_2 : P.C_2H_5$	214.23	$C_{14}H_{15}P$
6	— disulphide	$(C_2H_5)_2 : S_2$	122.22	$C_4H_{10}S_2$
7	— dithiocarbonate	$CO : (SC_2H_5)_2$	150.23	$C_5H_{10}OS_2$
8	— ether	$C_2H_5.O.C_2H_5$	74.10	$C_4H_{10}O$
9	— fluoride	C_2H_5F	48.05	C_2H_5F
10	— formamide	$CHO.NH(C_2H_5)$	73.08	C_3H_7ON
11	— glycine	$CH_2(NH.C_2H_5)COOH$	103.10	$C_4H_9O_2N$
12	— glycollic acid	$CH_2(O.C_2H_5)COOH$	104.08	$C_4H_8O_3$
13	— hydrazine	$C_2H_5.NH.NH_2$	60.09	$C_2H_8N_2$
14	— hydrogen sulphate,	see Ethyl sulphuric acid		
15	— hydroxylamine β	$C_2H_5.NHOH$	61.08	C_2H_7ON
16	— isoamyl ether	$C_2H_5.O.C_5H_{11}$	116.16	$C_7H_{16}O$
17	— isobutyl ether	$C_2H_5.O.C_4H_9$	102.14	$C_6H_{14}O$
18	— isocyanide	$C_2H_5.NC$	55.07	C_3H_5N
19	— isopropyl ether	$C_2H_5.O.C_3H_7$	88.12	$C_5H_{12}O$
20	— iodide	C_2H_5I	155.97	C_2H_5I
21	— malonic acid	$C_2H_5.CH(COOH)_2$	150.11	$C_5H_8O_4$
22	— mercaptan	$C_2H_5.SH$	62.12	C_2H_6S
23	— methyl acetic acid	$C_2H_5.CH(CH_3).COOH$	102.11	$C_5H_{10}O_2$
24	— — benzene, *o*	$C_2H_5.C_6H_4.CH_3$	120.14	C_9H_{12}
25	— — —, *m*	,, ,,	120.14	,,
26	— — —, *p*	,, ,,	120.14	,,
27	— — ether	$C_2H_5.O.CH_3$	60.08	C_3H_8O
28	— — glyoxalin	$C_3H_5N_2.C_2H_5$	110.13	$C_6H_{10}N_2$
29	— — ketone	$C_2H_5.CO.CH_3$	72.08	C_4H_8O
30	— — protocatechuic aldehyde	$C_6H_3(CHO)(OCH_3)(OC_2H_5)$	180.15	$C_{10}H_{12}O_3$
31	— — sulphide	$C_2H_5.S.CH_3$	76.14	C_3H_8S
32	— monothio carbonate	$CS(OC_2H_5)_2$	134.17	$C_5H_{10}O_2S$
33	— naphthalene, *a*	$C_{10}H_7.C_2H_5$	156.16	$C_{12}H_{12}$
34	— —, β	,, ,,	156.16	,,
35	— naphthylamine, *a*	$C_{10}H_7.NH.C_2H_5$	171.17	$C_{12}H_{13}N$
36	— —, β	,, ,,	171.17	,,
37	— naphthyl ether, *a*	$C_{10}H_7.O.C_2H_5$	172.16	$C_{12}H_{14}O$
38	— — —, β	$C_{10}H_7.O.C_2H_5$	172.16	$C_{12}H_{12}O$
39	— nitrate	$C_2H_5.NO_3$	91.06	$C_2H_5O_3N$

Density = 1.	Solubility in			M.P. °C.	B.P. °C.	
	Water.	Alcohol.	Ether.			
	v.s.s.	s.		39.5	subl.	1
0.89	i.			liq.	d.	2
0.8981	h.s.	s.	s.	60		3
		s.		liq.	285—287	4
		s.	s. C_6H_6	liq.	293	5
0.933/20°	v.s.s.				153/730	6
1.085/19°					196—197	7
0.7201/15°	1 : 12/17.5°	m.		− 117.6	34.6	8
1.7	s.	v.s. (abs.)			− 32	9
0.952/21°					199	10
	s.	s.		d. > 160		11
				liq.	206—207	12
	v.s.	v.s.	s.		99.5/709	13
						14
0.8827/7.5°	m.	m.	m.		59—60	15
0.764/18°					112	16
0.7507					79	17
0.7591/4°	v.s.				78.1	18
0.7447/0°					54	19
1.9433/15°	s.s.	s.	s.	− 108.5	72.3	20
	53 : 100/0°	s.	s.	110	160 d.	21
0.8391/20°	1.5 : 100	s.		− 22	35.5—36.1	22
0.938/24°				liq.	175	23
0.873/16°	i.	s.	s.	< −17	158—159	24
0.869/20°	i.	s.	s.	liq.	158—159	25
0.865/21°	i.	s.	s.	liq.	161—162	26
0.725/0°					10.8	27
0.982/15°	m.			liq.	212—213	28
0.8125/13°				− 85.9	79.6	29
	h.s.s.	s.s.	s.	73—74	subl.	30
0.837/20°					67	31
1.032/1°	i.	v.s.	v.s.		161—162	32
1.0184/10°					251—262	33
				− 14	251	34
					292—323/745mm.	35
				193	315—316	36
1.0746/0°				5.5	272	37
				37	274—275	38
1.1123/15.5°	i.			− 112	86.3/728	39

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Ethyl nitrite	$C_2H_5.NO_2$	75.06	$C_2H_5O_2N$
2	— nitrolic acid	$CH_3.C(NO_2):NOH$	104.06	$C_2H_4O_3N_2$
3	— ortho carbonate	$C(OC_2H_5)_4$	192.21	$C_9H_{20}O_4$
4	— phenol, o	$C_2H_5.C_6H_4.OH$	122.12	$C_8H_{10}O$
5	— —, p	,, ,,	122.12	,,
6	— phenyl acetylene	$C_6H_5.C\ :\ C.C_2H_5$	130.13	$C_{10}H_{10}$
7	— — carbaminate, see	Phenyl urethane		
8	— — carbinol	$C_6H_5.CHOH.C_2H_5$	136.14	$C_9H_{12}O$
9	— — hydrazine, a	$C_6H_5.N(C_2H_5).NH_2$	136.16	$C_8H_{12}N_2$
10	— — —, β	$C_6H_5.NH.NH.C_2H_5$	136.16	,,
11	— — ketone	$C_6H_5.CO.C_2H_5$	134.13	$C_9H_{10}O$
12	— — sulphone	$C_6H_5.SO_2.C_2H_5$	170.18	$C_8H_{10}O_2S$
13	— — urea	$(C_2H_5)HN.CO.NH(C_6H_5)$	164.16	$C_9H_{12}ON_2$
14	— phosphine	$(C_2H_5)H_2P$	62.11	C_2H_7P
15	— propyl carbinol	$C_2H_5.CH.CHOH.C_2H_5$	102.14	$C_6H_{14}O$
16	— — ether	$C_2H_5.O.C_3H_7$	88.12	$C_5H_{12}O$
17	— — ketone	$C_2H_5.CO.C_3H_7$	100.13	$C_6H_{12}O$
18	— pyridine, a	$C_5H_4N.C_2H_5$	107.12	C_7H_9N
19	— silicate	$Si(O_2H_5)_4$	208.30	$C_8H_{20}O_4Si$
20	— sulphate	$(C_2H_5O)_2SO_2$	154.16	$C_4H_{10}O_4S$
21	— sulphide	$(C_2H_5)_2S$	90.16	$C_4H_{10}S$
22	— sulphinic acid	$C_2H_5.SO_2H$	94.12	$C_2H_6O_2S$
23	— sulphite	$(C_2H_5)_2SO$	138.16	$C_4H_{10}O_3S$
24	— sulphochloride	$C_2H_5.SO_2Cl$	128.57	$C_2H_5O_2SCl$
25	— sulphone	$(C_2H_5)_2SO_2$	122.16	$C_4H_{10}O_2S$
26	— sulphonic acid	$C_2H_5.SO_2.OH$	110.12	$C_2H_6O_3S$
27	— sulphoxide	$(C_2H_5)_2SO$	106.16	$C_4H_{10}OS$
28	— sulphuric acid	$C_2H_5.HSO_4$	126.12	$C_2H_6O_4S$
29	— thiocyanate	$C_2H_5.SCN$	87.11	C_3H_5NS
30	— —, $iso.$	$C_2H_5.NCS$	87.11	,,
31	— toluene, see	Ethyl methyl benzene		
32	— vinyl ether	$C_2H_5.O.C_2H_3$	72.08	C_4H_8O
33	— xylene, 1:3:5	$C_2H_5.C_6H_3:(CH_3)_2$	134.16	$C_{10}H_{14}$
34	— —, 1:3:4	,,	134.16	,,
35	Ethylene	$CH_2:CH_2$	28.04	C_2H_4
36	— bromide	$C_2H_4Br_2$	187.88	$C_2H_4Br_2$
37	— chlorhydrin	$CH_2Cl.CH_2OH$	80.50	C_2H_5OCl
38	— chloride	$C_2H_4Cl_2$	98.96	$C_2H_4Cl_2$
39	— cyanhydrin	$CH_2OH.CH_2CN$	71.07	C_3H_5ON

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.9/15.5°	i.	m.		liq.	16.4	1
	s.		s.	88		2
0.9197/18.5°				liq.	158—159	3
1.0371/0°				< —18	198—199/720	4
	i.	s.	s.	46	218.5—219	5
0.923/21°					201—203	6
						7
0.99/15°		s.	s.	liq.	210—211/750	8
1.018/15°				liq.	237	9
	s.s.	s.	s.	liq.	237—240/750	10
1.0141/15°				14.5	215/746	11
	c.s.s.	s.	s.	42	>300	12
		s.		99		13
<H₂O				liq.	25	14
0.8188/20°		s.			135	15
0.7545/0°					60	16
0.818/17.5°				liq.	123/763.4	17
0.9498/0°					148—150	18
0.933	d.				165	19
1.1837/19°	i.	h.d.		- 24.5	134.5/12mm.	20
0.8368/20°	i.			liq.	92/754mm.	21
			s. alk.			22
1.1063/0°		s.			66.5/26mm.	23
1.357/20°	d.		-	29	122 d.	24
	1:6.4			73—74	248	25
	del., v.s.	s.	s. alk.			26
	s.			4—6	88—89/15mm.	27
1.316/16°			s. alk.	liq.	d.	28
0.9953/23.4°	i.	m.	m.		141—142	29
1.019/0°	l.	s.	s.	- 5.9	132—133	30
					/753mm.	31
0.7625/14.5°	s.s.	s			35.5	32
0.861/20°	i.		s.	liq.	185	33
0.8783/20°				liq.	183—184	34
	1:8 vol.	2:1	2:1	- 169.5	- 103	35
2.1823/20°	i.	s.		9.95	131,6/769.8	36
1.24/8°	s.	s.	s.		128	37
1.2521/20°	i.	s.		- 40	57.5/751mm.	38
1.059/0°	m.	m.	2.3 : 100/15°	liq.	221/753mm.	39

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Ethylene cyanide	$C_2H_4(CN)_2$	80.07	$C_4H_4N_2$
2 ---diamine	$C_2H_4(NH_2)_2.H_2O$	78.11	$C_2H_9N_2$
3 — diphenyl ether	$(C_6H_5O)_2C_2H_4$	214.18	$C_{14}H_{14}O_2$
4 — disulphonic acid	$C_2H_4(SO_3H)_2$	190.18	$C_2H_6O_6S_2$
5 — ethylidene oxide	$CH_3.CH\begin{smallmatrix}OCH_2\\ \mid \\ OCH_2\end{smallmatrix}$	88.08	$C_4H_8O_2$
6 — iodide	$C_2H_4I_2$	281.88	$C_2H_4I_2$
7 — mercaptan	$C_2H_4(SH)_2$	94.18	$C_2H_6S_2$
8 — nitrate	$C_2H_4(NO_3)_2$	152.06	$C_2H_4O_6N_2$
9 — nitrite	$C_2H_4(NO_2)_2$	120.06	$C_2H_4O_4N_2$
10 — oxide	C_2H_4O	44.04	C_2H_4O
11 --- sulphone	$(C_6H_5.SO_2)_2C_2H_4$	310.30	$C_{14}H_{14}O_4S_2$
12 — sulphide	$(C_2H_4S)_2$	120.20	$C_4H_8S_2$
13 — thiocyanate	$C_2H_4(SCN)_2$	144.19	$C_4H_4N_2S_2$
14 — urea	$CO:(NH.CH_2)_2$	86.08	$C_3H_6ON_2$
15 Ethylidene acetone	$CH_3.CO.CH:CH.CH_3$	84.09	C_5H_8O
16 — cyanhydrin	$CH_3.CH(OH)CN$	71.07	C_3H_5ON
17 — urea	$CO:(NH)_2:CH.CH_3$	86.08	$C_3H_6ON_2$
18 — urethane	$C_2H_4(NH.COO.C_2H_5)_2$	204.19	$C_8H_{16}O_4N_2$
19 Eugenic acid	$C_6H_2(OH)(OCH_3)(C_3H_5)\begin{smallmatrix}\\COOH\end{smallmatrix}$	208.15	$C_{11}H_{12}O_4$
20 Eugenol, 4:3:1	$C_6H_3(OH)(OCH_3)CH_2.\begin{smallmatrix}\\CH:CH_2\end{smallmatrix}$	164.15	$C_{10}H_{12}O_2$
21 Eupittonic acid	$C_{19}H_8O_3(OCH_3)_6$	479.33	$C_{25}H_{26}O_9$
22 Euxanthic acid	$C_{13}H_{10}O_5$	246.15	$C_{13}H_{10}O_5$
23 Euxanthinic acid	$C_{19}H_{18}O_{10}.3H_2O$	460.29	$C_{19}H_{18}O_{10}$
24 Euxanthone	$OH.C_6H_3\begin{smallmatrix}CO\\ \diagup\diagdown\\ O\end{smallmatrix}C_6H_3.OH$	228.13	$C_{12}H_8O_4$
25 Evernic acid	$C_{17}H_{16}O_7$	332.21	$C_{17}H_{16}O_7$
26 Everniine	$C_9H_{14}O_7$	198.14	$C_9H_{14}O_7$
27 Everninic acid	$C_6H_3(OH)_2COOH.H_2O$	200.15	$C_8H_{10}O_4$
28 Fenchene	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
29 Fenchone	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
30 Ferulic acid, 3:4:1	$C_6H_3(OCH_3)OH.C_2H_2.\begin{smallmatrix}\\COOH\end{smallmatrix}$	194.13	$C_{10}H_{10}O_4$
31 Fisetin	$\begin{smallmatrix}OH\\ \\ C_6H_3\end{smallmatrix}\begin{smallmatrix}O-C.C_6H_3(OH)_2\\ \parallel\\ CO.C(OH).4H_2O\end{smallmatrix}$	358.22	$C_{15}H_{10}O_6$

Density $H_2O=1$.	Water.	Solubility in Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.23/45°	s.	s.	s.s.	54.5	158—160/20	1
0.970/15°	s.		v.s.s.	10	116	2
	i.	h.s.	s	98.5		3
	del.	s.		94		4
1.002	1:1.5			82.5		5
2.07		s.		81—82	d.	6
1.123/23°	s. alk.	s.		liq.	146	7
1.472		s.		liq.	d.	8
1.2156/0°	i.	s.	s.	37.5	subl.	9
0.896/0°	v.s.	v.s.	v.s.	liq.	13.5/746mm.	10
	i.	h.s.s.	s. acetic.	179.5—180		11
	i.	s.	s.	110	subl. 200	12
	h.s.	...		90	d.	13
			s. CHCl$_3$	131		14
0.861/15°	s.				122—123/741	15
	s.	s.	s.		182—184 d.	16
	v.s.s.	s.s.	v.s.s.	154	d. 100	17
	h.s.	s.	s.	125—126	d.	18
	c.s.s.	s.	s.	124		19
1.0703/14°	v.s.s.	s.	s.	liq.	247.5	20
	s. alk. to B	h.s.s. (abs.)	s. acetic	d. 200		21
	h.s.	s. (abs.)	s. alk.	200—202		22
	h.s.	h.s.	v.s.	d. 160		23
	s. alk.	h.s.	s.s.	237—238		24
	h.s.s.	s.	s.	164—170		25
	v.s.	i.				26
	h.s.	s.	s.	157		27
0.864/20°					158—160	28
0.9465/19°		s.		5—6	194—195	29
	h.s.	c.s.	s.s.	170	d.	30
		s.		330 d.		31

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Flavaniline	$C_{16}H_{12}N.NH_2$	234.21	$C_{16}H_{14}N_2$
2	Flaveanhydride	$CN.CS.NH_2$	86.11	$C_2H_2N_2S$
3	Flavone	$C_6H_4 \begin{array}{c} O-C.C_6H_5 \\ \| \\ CO.CH \end{array}$	222.16	$C_{15}H_{10}O_2$
4	Flavopurpurin, see	Trihydroxy anthraquinone		
5	Fluorane	$\begin{array}{c} C_6H_4.C:(C_6H_4)_2:O \\ \\ CO-O \end{array}$	300.20	$C_{20}H_{12}O_3$
6	Fluoranthene	$C_{15}H_{10}$	190.16	$C_{15}H_{10}$
7	Fluor benzene	C_6H_5F	96.07	C_6H_5F
8	— benzoic acid	$C_6H_4F.COOH$	140.08	$C_7H_5O_2F$
9	Fluorene	$(C_6H_4)_2:CH_2$	166.15	$C_{13}H_{10}$
10	— alcohol	$(C_6H_4)_2:CHOH$	182.15	$C_{13}H_{10}O$
11	Fluorenone, di- phenylene ketone	$(C_6H_4)_2:CO$	180.13	$C_{13}H_8O$
12	Fluoresceïn	$C_{20}H_{12}O_5$	332.10	$C_{20}H_{12}O_5$
13	Formaldehyde	$H.CHO$	30.02	CH_2O
14	Formaldoxime	$H.CH:NOH$	45.04	CH_3ON
15	Formamide	$H.CO.NH_2$	45.04	CH_3ON
16	— oxime	$CH(NH_2):NOH$	60.06	CH_4ON_2
17	Formanilide	$C_6H_5.NH.CHO$	121.10	C_7H_7ON
18	Formic acid	$H.COOH$	46.02	CH_2O_2
19	Formate, calcium	$(H.COO)_2Ca$	130.10	$C_2H_2O_4Ca$
20	—, copper	$(H.COO)_2Cu(.4H_2O)$	153.60	$C_2H_2O_4Cu$
21	—, lead	$(H.COO)_2Pb$	297.23	$C_2H_2O_4Pb$
22	—, sodium	$H.COONa$	68.01	CHO_2Na
23	—, allyl	$H.COO.C_3H_5$	86.07	$C_4H_6O_2$
24	—, iso amyl	$H.COO.C_5H_{11}$	116.13	$C_6H_{12}O_2$
25	—, ethyl	$H.COO.C_2H_5$	74.06	$C_3H_6O_2$
26	—, methyl	$H.COO.CH_3$	60.04	$C_2H_4O_2$
27	Formyl diphenyl- amine	$CHO.N(C_6H_5)_2$	197.16	$C_{13}H_{11}ON$
28	— hydrazine	$HCO.NH.NH_2$	60.06	CH_4ON_2
29	Frangulin	$C_{21}H_{20}O_9$	416.26	$C_{21}H_{20}O_9$
30	Fraxine	$C_{16}H_{18}O_{10}$	370.22	$C_{16}H_{18}O_{10}$
31	Fulminate, mercuric	$(CNO)_2Hg.\frac{1}{2}H_2O$	293.65	$C_2O_2N_2Hg$
32	—, silver	$CNOAg$	149.90	$CNOAg$
33	Fulminuric acid	$C_3H_3N_3O_3$	129.07	$C_3H_3O_3N_3$
34	Fumaric acid	$C_2H_2(COOH)_2$	116.05	$C_4H_4O_4$

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C	B.P. °C	
	v.s.s.	s.	s. C$_6$H$_6$	97		1
	s.	d.	v.s.	d. 87—90		2
	i.	s.	s.	97		3
						4
		s.		182		5
1.0236/20°	s. acetic	h.s.	s., s. CS$_2$	109—110	250—251/60	6
					84.5	7
	h.s.	s.	s.	182		8
		h.s.	s.	115	294—295	9
		s.	s.	153		10
	i.	v.s.	v.s.		341.5	11
	h.s.s.	s.	s.	d.		12
	s.	s.		− 92	− 21	13
					84—85	14
1.1337/14.1°	s.	s.		− 1	85—95/0.5	15
	s.	s.	s.	114—115	d.	16
	s.	s.	s.	50	271	17
1.2256/15°	m.	s.	s.	8.5	100.6	18
2.015	s.	i.				19
1.831	s.					20
4.56	1:63/16°	i.				21
1.919	v.s.	s.				22
0.93/17.5°		s.		liq.	81—83	23
0.894/0°	1:325/22°			liq.	130.4	24
0.9445/0°	11:10	s.	s.	− 78.9	54.4	25
0.986/11°				− 100.4	32.2	26
	s.			73—74	210—220 in vac.	27
				54		28
	i.	h.s.	h.s.	286		29
	h.s.	h.s.		190		30
4.42 (an.)	h.s.	s.		expl.		31
	1:36, h.			expl.		32
	s.	s.	s.	136—139		33
1.625	1:150/16.5°	s.	s.	286—287	200 subl.	34

N

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Furane	$\begin{matrix} CH:CH \\ \| \qquad \rangle O \\ CH:CH \end{matrix}$	68.05	C_4H_4O
2 Furfural	$C_4H_3O.CHO$	96.06	$C_5H_4O_2$
3 Furfur alcohol	$C_4H_3O.CH_2OH$	98.07	$C_5H_6O_2$
4 – amide	$(C_5H_4O)_3N_2$	268.19	$C_{15}H_{12}O_3N_2$
5 Furfurin	$C_{15}H_{12}N_2O_3$	268.19	,,
6 Furyl amine	$C_4H_3O.CH_2.NH_2$	97.09	C_5H_7ON
7 Galactose, l	$C_6H_{12}O_6$	180.13	$C_6H_{12}O_6$
8 –, d	,,	180.13	,,
9 Galleïn	$C_{20}H_{10}O_7$	362.18	$C_{20}H_{10}O_7$
10 Gallic acid, 3 : 4 : 5 : 1	$C_6H_2(OH)_3COOH_2O$	188.10	$C_7H_6O_5$
11 Gallin	$C_{20}H_{14}O_7$	366.21	$C_{20}H_{14}O_7$
12 Gaultherin	$C_{14}H_{18}O.O.C_6H_4.COOCH_3$	314.21	$C_{14}H_{18}O_8$
13 Gaultherinic acid	$C_{36}H_{54}O_5$	582.61	$C_{36}H_{54}O_5$
14 Gentisin	$C_{14}H_{10}O_5$	258.15	$C_{14}H_{10}O_5$
15 Geraniol	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
16 Gluconic acid, d	$C_5H_6(OH)_5COOH$	196.13	$C_6H_{12}O_7$
17 Glucose	$C_6H_{12}O_6.H_2O$	198.15	$C_6H_{12}O_6$
18 –, anhydr.	$C_6H_{12}O_6$	180.13	,,
19 – phenylhydrazone, a	$C_6H_{12}O_6(N_2H.C_6H_5)$	270.22	$C_{12}H_{18}O_5N_2$
20 Glucosamine, d	$C_6H_{13}O_5N$	179.14	$C_6H_{13}O_5N$
21 Glucosazone, a	$C_6H_{10}O_4(N_2H.C_6H_5)_2$	358.31	$C_{18}H_{22}O_4N_2$
22 Glucosoxime, a	$C_6H_{12}O_5:NOH$	195.14	$C_6H_{13}O_6N$
23 Glucosone	$C_6H_8O_4.CO.CHO$	178.11	$C_6H_{10}O_6$
24 Glucuronic acid	$CHO.(CHOH)_4.COOH$	194.11	$C_6H_{10}O_7$
25 Glutamine	$C_3H_5(NH_2)(CONH_2)COOH$	146.13	$C_5H_{10}O_3N_2$
26 Glutaminic acid, i	$C_3H_5(NH_2)(COOH)_2$	147.11	$C_5H_9O_4N$
27 Glutaric acid	$HOOC.(CH_2)_3.COOH$	132.09	$C_5H_8O_4$
28 Glyceric acid, a	$CH_2OH.CHOH.COOH$	106.06	$C_3H_6O_4$
29 Glycerol	$C_3H_5(OH)_3$	92.08	$C_3H_8O_3$
30 – aldehyde	$CH_2OH.CHOH.CHO$	90.06	$C_3H_6O_3$
31 – diethyl ether, aa	$(CH_2O.C_2H_5)_2:CHOH$	148.16	$C_7H_{16}O_3$
32 – monoethyl ether, a	$(CH_2O.C_2H_5).CHOH.CH_2OH$	120.12	$C_5H_{12}O_3$
33 – mercaptan dithioglycerol	$C_3H_5(OH)(SH)_2$	124.20	$C_3H_8OS_2$
34 ––, monothioglycerol	$C_3H_5(OH)_2(SH)$	108.14	$C_3H_8O_2S$
35 ––, trithioglycerol	$C_3H_5(SH)_3$	140.26	$C_3H_8S_3$
36 – phosphoric acid	$C_3H_5(OH)_2OP(OH)_2$	156.13	$C_3H_9O_5P$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.9086/21.6	i.	s.	s.	liq.	31.6	1
1.1636/13.5°	1:11/13°	s.	s.	− 36.5	158.5—159	2
1.1355/20°	s.	s.	s.	200 subl.	166—170/725	3
	c.i.	s.	s.	117	d. 250	4
	1:135/100°	v.s.	v.s.	116		5
$< H_2O$	m.			liq.	145/754mm.	6
	s.	v.s.s.		162—163		7
-	s.			168		8
	h.s.s.	v.s.	s.s., s. alk.	d.		9
1.694/4°	1:3/100°	28:100/15°	2.5:100/15°		253 d.	10
	s.	s.	s.			11
	s.	s.	i.	251—252	subl.	12
	s.s.	s.		195		13
	v.s.s.	v.s.s.	v.s.s.	267	300—400 subl & d.	14
0.8965/0°	i.	m.	m.		230	15
	v.s.	i.				16
1.54 − 1.57	98:100/18°	s.		82		17
	s.	v.s.		146		18
	s.	h.s.	l	115, β 144		19
	s.s.	s.	i.	110 d.		20
	i.	h.s.		145, β 204 d.		21
	v.s.	s.s.	i.	136—137		22
	s.	s.	i.			23
		s.		aq. 175		24
	1:25/16°	i.	i.			25
1.538	1:100/16°	s.s.	i.	198		26
1.1919/106.4°	1:1.2/14°	v.s.	v.s.	97.5	200/20mm.	27
	r.	m.	i.	liq.		28
1.2604/20°	m.	s.	i.	20	290	29
	s.s.	v.s.s.	v.s.s.	132		30
0.920/21°					191	31
					225—230	32
1.34	i.	s.	i.	liq.		33
	s.s.	s.	i.	liq.		34
1.29	i.	s.	i.	liq.		35
1.39	s., h.d.	s.		d.		36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Glyceryl chloride	$C_3H_5Cl_3$	147.44	$C_3H_5Cl_3$
2	— ether	$(C_3H_5)_2O_3$	130.11	$C_6H_{10}O_3$
3	**Glycide**	$O \begin{matrix} CH.CH_2OH \\ \| \\ CH_2 \end{matrix}$	74.06	$O_3H_6O_2$
4	Glycine, see	Amino acetic acid		
5	Glycocyamine	$C(NH)(NH_2)NH.CH_2.$ $COOH$	117.09	$C_3H_7O_2N_3$
6	Glycol	$C_2H_4(OH)_2$	62.06	$C_2H_6O_2$
7	— acetate	$C_2H_4(OH)OOC.CH_3$	104.08	$C_4H_8O_3$
8	— amide	$CH_2OH.COONH_2$	75.06	$C_2H_5O_2N$
9	— di-acetate	$C_2H_4(OOC.CH_3)_2$	146.11	$C_6H_{10}O_4$
10	Glycollic acid	$CH_2OH.COOH$	76.04	$C_2H_4O_3$
11	Glycollide	$\left(\begin{matrix} CH_2 \\ \| \\ CO \end{matrix} \right> O \right)_x$	(58.03)	
12	Glycol thiourea	$C_3H_4N_2SO$	116.13	$C_3H_4ON_2S$
13	Glyoxal	$CHO.CHO$	58.03	$C_2H_2O_2$
14	Glyoxaline	$CH \begin{matrix} NH.CH \\ \| \\ N——CH \end{matrix}$	68.07	$C_3H_4N_2$
15	Glyoxime	$(CH:NOH).(CH:NOH)$	88.06	$C_2H_4O_2N_2$
16	Glyoxylic acid	$CHO.COOH.H_2O$	92.05	$C_2H_4O_3$
17	Guaiacol, 1 : 2	$C_6H_4(OH)OCH_3$	124.10	$C_7H_8O_2$
18	Guaiacol carbonate	$C_{15}H_{14}O_5$	274.19	$C_{15}H_{14}O_5$
19	Guanidine. (carbamidine)	$NH:C:(NH_2)_2$	59.08	CH_5N_3
20	Guanine	$C_5H_5N_5O$	151.12	$C_5H_5ON_5$
21	Hæmateïn	$C_{16}H_{12}O_6$	300.18	$C_{16}H_{12}O_6$
22	Hæmatin	$Fe(C_{16}H_{16}N_2O_2)_2$	592.30	$C_{32}H_{32}O_4N_4Fe$
23	Hæmatoxylin	$C_{16}H_{14}O_5.3H_2O$	356.24	$C_{16}H_{14}O_5$
24	Helicin	$C_{13}H_{16}O_7.\tfrac{3}{4}H_2O$	297.71	$C_{13}H_{16}O_7$
25	Heliotropin, see	Piperonal		
26	Hemimellitic acid,1 :2 :3	$C_6H_3(COOH)_3.2H_2O$	246.12	$C_9H_6O_6$
27	Hemipinic acid,3 :4 :1 :3	$C_6H_3(OCH_3)_2(COOH)_2.2H_2O$	262.16	$C_{10}H_{10}O_6$
28	— —, 4 : 5 : 1 : 2	”	226.13	”
29	— —, 5 :6 :1 :2	$C_6H_2(OCH_3)_2(COOH)_2$	226.13	$C_{10}H_{10}O_6$
30	Heptamethylene, see	Cyclo heptane		

Density H₂O=1.	Water.	Solubility in—Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.417/15°				liq.	154—156	1
1.16/16°	m.	m.	m.	liq.	171—172	2
1.165/0°	m.	m.	m.		162/751mm.	3
						4
	1:227/ 14.5°	i.	i.	– 11.2		5
1.1098/25°	m.	m.	i.	– 17.4	197/260mm.	6
>H₂O	m.	m.		liq.	182	7
	s.	s.s.		117—118		8
	1:7	s.	b	liq.	186—187	9
	s.	m.	m.	80	d.	10
	h.v.s.s			220		11
	h.s.	i.	i.	d. 200		12
	v.s.	v.s.	s.	15	51	13
	s.	s.	s.	88—89	255	14
	h.s.	s.	s.	178	subl	15
	s.		vol. steam.	syrup.		16
1 1385/15°	1:60/15°	s	s.	32	205	17
				86		18
	s.					19
	i.			d		20
	s.s.	s.s.	s.s.			21
	i.	i.	i.			22
	h.s.	s.	s.	100—120		23
	h.v.s.	s.	j.	an. 175		24
						25
	3.15:100/19°		s	196 d.		26
	c.s.s.	s.		184—185 d		27
				178		28
				180		29
						30

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Heptane, 1 norm.	$CH_3.(CH_2)_5.CH_3$	100.16	C_7H_{16}
2	—, 2. ethyl *iso* amyl	$CH_3.(CH_2)_3.CH:(CH_3)_2$	100.16	,,
3	—, 3. triethyl methane	$CH(C_2H_5)_3$	100.16	,,
4	—, 4. dimethyl diethyl methane	$(CH_3)_2:C:(C_2H_5)_2$	100.16	,,
5	Heptine, œnanthine	$CH_3(CH_2)_4.C:CH$	96.13	C_7H_{12}
6	Heptyl alcohol, 1 nor.	$C_7H_{15}OH$	116.16	$C_7H_{16}O$
7	——, 2. dipropyl carbinol	$CH_3.(CH_2)_2.CHOH.(CH_2)_2.$ CH_3	116.16	,,
8	——, 3. di-isoproyyl carbinol	$(CH_3)_2:CH.CHOH.CH:$ $(CH_3)_2$	116.16	,,
9	——, 4. triethyl carbinol	$(C_2H_5)_3C.OH$	116.16	,,
10	——, 5. dimethyl isobutyl carbinol	$(CH_3)_2:COH.CH_2.CH:$ $(CH_3)_2$	116.16	,,
11	——, 6. pentamethyl ethol	$(CH_3)_3C.C(CH_3)_2OH$	116.16	,,
12	— aldehyde, œnanthol	$C_6H_{13}.CHO$	114.15	$C_7H_{14}O$
13	Heptylene, norm.	C_7H_{14}	98.15	C_7H_{14}
14	Heptylic acid, norm.	$C_6H_{13}.COOH$	130.15	$C_7H_{14}O_2$
15	——, iso	,, ,,	130.15	,,
16	Heptylate, ethyl	$CH_3.(CH_2)_5.COOC_2H_5$	158.19	$C_9H_{18}O_2$
17	Heptylic anhydride	$(C_6H_{13}.CO)_2:O$	242.28	$C_{14}H_{26}O_3$
18	Hesperidin	$C_{22}H_{26}O_{12}$	482.92	$C_{22}H_{26}O_{12}$
19	Hexa chlor benzene	C_6Cl_6	285.39	C_6Cl_6
20	— ethane	C_2Cl_6	236.77	C_2Cl_6
21	— decane, dioctyl	$C_{16}H_{34}$	226.35	$C_{16}H_{34}$
22	— ethyl benzene	$C_6(C_2H_5)_6$	246.33	$C_{18}H_{30}$
23	— hydro benzene, see	Cyclo hexane		
24	—— benzoic acid	$C_6H_5(H_6)COOH$	128.13	$C_7H_{12}O_2$
25	—— cumene	$C_9H_{12}(H_6)$	126.19	C_9H_{18}
26	—— cymene	$CH_3.C_6H_4(H_6).C_3H_7$	140.21	$C_{10}H_{20}$
27	—— phenol, see	Cyclo hexanol		
28	—— salicylic acid	$OH.C_6H_4(H_6)COOH$	144.13	$C_7H_{10}O_3$
29	—— toluene	$C_6H_5(H_6)CH_3$	98.15	C_7H_{14}
30	—— m xylene	$C_6H_4(H_6)(CH_3)_2$	112.17	C_8H_{16}
31	Hexa hydroxy benzene	$C_6(OH)_6$	174.08	$C_6H_6O_6$
32	— methyl benzene	$C_6(CH_3)_6$	162.20	$C_{12}H_{18}$
33	— methylene tetramine	$(CH_2)_6N_4.6H_2O$	248.27	$C_6H_{12}N_4$

Density $H_2O=1.$	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P °C.	B.P. °C.	
0.6886/15°		s.	s.	liq.	97.5—98.5	1
0.6819/17°		s.	s.	liq.	90.3	2
0.689/27°		s.	s	liq	95—98	3
0.711/0°		s.	s.	liq.	87	4
0.8031/20°				liq.	110—112	5
0.830/16°	i.	s.	s.	− 35.5	172.5—173	6
0.8200/20°		s.	s.	liq.	154—155	7
0.8288/20°	v.s.s	s.	s.	liq.	131—132	8
0.8402/20°	s.s.	s.	s.	liq.	143—144	9
	s.s.	s.	s.	liq.	130—133	10
		s.	s.	17	131	11
0.827/17°	s.s.	s.		liq.	155	12
0.703/19°		s.		liq.	98—99	13
0.9345/0°		s.		− 12	221.5	14
	1 : 100 c.			liq.	211.5/746	15
0.8716/20°				liq.	188	16
0.92/11°				17	268—271	17
	1 : 5000 h.	s.s.	i.	d. 251		18
1.569/236°	s. C_6H_6.	h.s.s.	s.s.	227	326	19
2.011	i.	s.	s.		187	20
0.7754/18°		m.	m.	20	287.5	21
	i.	s.	v s.	129	305	22
						23
	s.s.	s.	s.	30	232—233	24
0.787/20°					137	25
0.8116/17°				liq.	153—158	26
						27
		s	s.	111		28
0.772/4°					101	29
0.78/0°					119.5—120	30
	s.s.	s.s.	s.s.	200 d.		31
	s.s.	v.s. C_6H_6	164 subl.	264		32
	s.	1 : 14 c. 1 : 7 h.	s. ac	15	d.	33

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Hexane, 1.norm.	$CH_3.(CH_2)_4.CH_3$	86.14	C_6H_{14}
2 —, 2. ethyl isobutyl	$C_2H_5.CH:(CH_3)_2$	86.14	,,
3 —, 3. di-isopropyl	$(CH_3)_2:CH.CH:(CH_3)_2$	86.14	,,
4 —, 4. trimethyl ethyl methane	$CH_3)_3.C.(C_2H_5)$	86.14	,,
5 Hexa nitro diphenyl-amine	$[C_6H_2(NO_2)_3]_2NH$	439.17	$C_{12}H_5O_{12}N_7$
6 Hexine, diallyl	$CH_2:CH.CH_2.CH_2.CH:CH_2$	82.11	,,
7 Hexyl alcohol, 1. norm	$CH_3.(CH_2)_4.CH_2OH$	102.14	$C_6H_{14}O$
8 ——, 2. methyl butyl carbinol	$CH_3.CHOH.(CH_2)_3.CH_3$	102.14	,,
9 ——, 3. ethyl propyl carbinol	$C_2H_5.CHOH.(CH_2)_2.CH_3$	102.14	,,
10 ——, 4. pinacolyl alcohol	$(CH_3)_3.C.CHOH.CH_3$	102.14	,,
11 ——, 5. dimethyl propyl carbinol	$(CH_3)_2:COH.(CH_2)_3.CH_3$	102.14	,,
12 ——, 6. dimethyl iso propyl carbinol	$(CH_3)_2:COH.CH:(CH_3)_2$	102.14	,,
13 ——, 7. diethyl methyl carbinol	$(C_2H_5)_2:COH.CH_3$	102.14	,,
14 — aldehyde *iso.*	$(CH_3)_2:CH.(CH_2)_2.CHO$	100.13	$C_6H_{12}O$
15 Hexylene, β	$CH_3.(CH_2)_2.CH:CH.CH_3$	84.13	C_6H_{12}
16 — glycol, 1. norm.	$CH_3.(CH_2)_3.CHOH.CH_2OH$	118.14	$C_6H_{14}O_2$
17 ——, 2. diallyl hydrate	$(CH_3.CH.CH_2OH)_2$	118.14	,,
18 ——, 3. pinacone	$(CH_3)_2:(C.OH)_2:(CH_3)_2$	118.14	,,
19 — iodide	$C_6H_{12}I_2$	337.94	$C_6H_{12}I_2$
20 Hippuric acid	$C_6H_5.CO.NH.CH_2COOH$	179.14	$C_9H_9O_3N$
21 Homatropine	$C_{16}H_{21}NO_3$	275.27	$C_{16}H_{21}O_3N$
22 Homocinchonine	$C_{19}H_{22}N_2O$	294.29	$C_{19}H_{22}ON_2$
23 Homophthalic acid	$HOOC.C_6H_4.CH_2.COOH$	180.11	$C_9H_8O_4$
24 Homopyrrole, see	Methyl pyrrole		
25 Homosalicylic acid, see	Hydroxy toluic acid, 2:1:3		
26 Hydantoïc acid	$NH_2.CO.NH.CH_2.COOH$	118.08	$C_3H_6O_3N_2$
27 Hydantoïn	$CO\begin{array}{c}\diagup NH.CH_2\\ \diagdown NH.CO\end{array}$	100.07	$C_3H_4O_2N_2$
28 Hydracetamide	$(CH_3.CH)_3N_2$	112.15	$C_6H_{12}N_2$
29 **Hydracrylic acid**	$CH_2OH.CH_2.COOH$	90.06	$C_3H_6O_3$

Density H₂O=1.	Solubility in			M.P. °C.	B.P. °C.	
	Water.	Alcohol.	Ether.			
0.6630/17°		s.	s.	S.P. --94.3	68.8	1
0.7011/0°		s.	s.	liq.	62	2
0.67/17°		s.	s.	liq.	58.1	3
		s.	s.	liq.	49.5	4
	i.	i.	s alk	238 d.		5
0.6983/12°				liq.	59	6
0.8204/20°	s.s.	s.		liq.	157.2/741	7
0.8327/0°	v.s.s.	s.		liq.	136	8
0.8188/20°	v.s.s.	s.		liq.	135	9
0.8347/0°		s.		4	121—123	10
		s.		4	120—125	11
0.8232/19°	s.	s.		- 35	117—119 /740mm.	12
0.8237/20°		s.			121—122.5	13
	s.s.	s.		liq.	121/743	14
0.6997/0°		—		- 98.5	67.7—68.1	15
0.967/0°	s.	s.	s.	liq.	207	16
0.9638/0°				liq.	212—215	17
0.96718/15°	h.s.	h.s.		43—44	171—172	18
2.024/0°				liq.	d.	19
1.308	h.s.	h.s.	s s.	189	d.	20
	s.s.			99—100		21
	s.s.	1 : 140/10°	1 :371/10°	257—257		22
		v.s.		175—176		23
						24
						25
	c.s.s.	h.s.	v.s.s.	153—156 d.		26
	h.s.	s.		218—220		27
	s.	s.				28
	h.s.	s.	s.	liq.	d.	29

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Hydratropic acid	$C_6H_5.CH(CH_3)COOH$	150.13	$C_9H_{10}O_2$
2 Hydrazo benzene	$C_6H_5.NH.NH.C_6H_5$	148.18	$C_{12}H_{12}N_2$
3 — benzoic acid, o	$(NH.C_6H_4.COOH)_2$	272.19	$C_{14}H_{12}O_4N_2$
4 — — —, m	,, ,,	272.19	
5 — toluene, o	$CH_3.C_6H_4.NH.NH.C_6H_4.CH_3$	212.22	$C_{14}H_{16}N_2$
6 — —, m	,, ,,	212.22	,,
7 — —, p	,, ,,	212.22	,,
8 Hydrindene, 2 : 3	$C_6H_4:(CH_2)_3$	118.13	C_9H_{10}
9 Hydrindone, α	$C_6H_4\big\langle \begin{smallmatrix}CH_2\\CO\end{smallmatrix}\big\rangle CH_2$	132.11	C_9H_8O
10 —, β	$C_6H_4\big\langle \begin{smallmatrix}CH_2\\CH_2\end{smallmatrix}\big\rangle CO$	132.11	,,
11 Hydro-acridine, 5 : 10	$C_6H_4\big\langle \begin{smallmatrix}CH_2\\NH\end{smallmatrix}\big\rangle C_6H_4$	181.16	$C_{13}H_{11}N$
12 — anthranol, 10 : 9 : 10	$CH_2\big\langle \begin{smallmatrix}C_6H_4\\C_6H_4\end{smallmatrix}\big\rangle CHOH$	196.17	$C_{14}H_{12}O$
13 — benzamide	$(C_6H_5.CH_3N_2)$	298.27	$C_{21}H_{18}N_2$
14 — benzoin	$C_6H_5.(CHOH)_2.C_6H_5$	214.18	$C_{14}H_{14}O_2$
15 — carbostyril	C_9H_9NO	147.13	C_9H_9ON
16 — cinnamic acid	$C_6H_5.CH_2.CH_2COOH$	150.13	$C_9H_{10}O_2$
17 — cœrulignone	$(HO)_2:C_{12}H_4(OCH_3)_4$	306.22	$C_{16}H_{18}O_6$
18 — coumaric acid, o	$OH.C_6H_4.(CH_2)_2.COOH$	166.13	$C_9H_{10}O_3$
19 — — —, p	,, ,,	166.13	,,
20 — cyanic acid	HCN	27.02	CHN
21 — mellitic acid	$C_6H_6(COOH)_6$	348.16	$C_{12}H_{12}O_{12}$
22 — phenazine, 5 : 10	$C_6H_4:(NH)_2:C_6H_4$	182.16	$C_{12}H_{10}N_2$
23 — quinone, see	Dihydroxy benzene		
24 — — phthalein	$C_{20}H_{12}O_5$	332.20	$C_{20}H_{12}O_5$
25 Hydroxy acetophenone, o	$C_6H_4(OH).COCH_3$	136.10	$C_8H_8O_2$
26 — —, m	$C_6H_4(OH).COCH_3$	136.10	$C_8H_8O_2$
27 — — —, p	,, ,,	136.10	,,
28 — — — carboxylic acid	see Acetyl hydroxy benzoic acid		
29 — acrylic acid, β	$CHOH:CH.COOH$	88.05	$C_3H_4O_3$
30 — anthraquinone, 1	$C_6H_4:(CO)_2:C_6H_3OH$	224.13	$C_{14}H_8O_3$
31 — —, 2	,, ,,	224.13	,,

Density H$_2$O=1.	Water.	Solubility in—Alcohol.	Ether.	M.P. °C.	B.P. °C.	
				liq.	264—265	1
1.150	i.	5 : 100/16°	s.	131	d.	2
		h.s.				3
	i.	h.s.s.	s. alk.			4
		s.	s.	156	d.	5
		v.s.		liq.		6
		s.	s.	124	d.	7
0.957/15					176—176.5	8
1.011/45°	s.s.	v.s.		41—42	243—245	9
		s.	s.	61	220—225	10
	i.	h.s	s.	169	subl.	11
	h.s.	s.	s.	76		12
	i.	s	s.	110		13
	1:400/15°	h.s.		138		14
	i.	s.	s.	163		15
1.0710/48.7°	1:168/20°	s.	s.	48.7	279	16
	v.s.s.	h.s.	v.s.s.	190		17
	1:20/18°	s.	s.	82—83		18
	h.s.	s.	s.	128		19
0.697/18°	m.	m.	m.	— 14	26.11	20
		s.s.		d.		21
						22
						23
	h.v.s.s.	s.		232—234	d.	24
	h.v.s.	v.s	v.s.		96—97/10	25
				95—96		26
				110		27
						28
	s.	s.	s.	liq		29
	s. alk.	s.	s.	190	subl.	30
	h.s.	v.s.	v.s.	302	subl.	31

	Name.	Formula	Formula Weight.	Empirical Formula.
1	Hydroxy azobenzene, 4	$C_6H_5.N_2.C_6H_4OH$	198.16	$C_{12}H_{10}ON$
2	— —, 2	,, ,,	198.16	,,
3	— benzaldehyde, o	$HO.C_6H_4.CHO$	122.08	$C_7H_6O_2$
4	— —, m	,, ,,	122.08	,,
5	— —, p	,, ,,	122.08	,,
6	— benzoic acid, o	$C_6H_4OH.COOH$	138.08	$C_7H_6O_3$
7	— — —, m	,, ,,	138.08	,,
8	— — —, p	,, ,, (H_2O)	138.08	,,
9	— benzyl alcohol, o	$HO.C_6H_4.CH_2OH$	124.10	$C_7H_8O_2$
10	— — —, m	,, ,,	124.10	,,
11	— — —, p	,, ,,	124.10	,,
12	— butyric acid, α	$C_2H_5.CHOH.COOH$	104.08	$C_4H_8O_3$
13	— — —, β	$CH_3.CHOH.CH_2.COOH$	104.08	,,
14	— — —, γ	$CH_2OH.(CH_2)_2.COOH$	104.08	,,
15	— — —, aceton acid	$(CH_3)_2.COH.COOH$	104.08	,,
16	— caproic acid	$C_5H_{10}(OH).COOH$	132.13	$C_6H_{12}O_3$
17	— — —, diethyl glycollic acid	$(C_2H_5)_2:C(OH)COOH$	132.13	,,
18	— — —, α	$CH_3.(CH_2)_3.CHOH.COOH$	132.13	,,
19	— caprylic acid, α	$CH_3.(CH_2)_5.CHOH.COOH$	160.17	$C_8H_{16}O_3$
20	— citric acid	$C_3H_4(OH)_2(COOH)_3.H_2O$	226.11	$C_6H_8O_8$
21	— diphenyl, 4	$C_6H_5.C_6H_4.OH$	170.14	$C_{12}H_{10}O$
22	— diphenylamine, 4	$C_6H_5.NH.C_6H_4OH$	185.16	$C_{12}H_{11}ON$
23	— —, 3	,, ,,	185.16	,,
24	— ethyl amine, see	Amino ethyl alcohol		
25	— — piperidine	$C_5H_{10}.N.C_2H_4OH$	129.17	$C_7H_{15}ON$
26	— glutaric acid, α	$C_3H_5(OH)(COOH)_2$	148.09	$C_5H_8O_5$
27	— hydroquinone,1:2:4	$C_6H_3(OH)_3$	126.08	$C_6H_6O_3$
28	— — triethyl ether, 1:2:4	$C_6H_3(OC_2H_5)_3$	210.22	$C_{12}H_{18}O_3$
29	— isocaprylic acid	$[(CH_3)_2:CH]_2:COH.COOH$	160.17	$C_8H_{16}O_3$
30	— methyl benzoic acid, o	$CH_2OH.C_6H_4.COOH$	152.10	$C_8H_8O_3$
31	— naphthoquinone, 1:4:5	$C_{10}H_5O_2.OH$	174.10	$C_{10}H_6O_3$
32	— —, 1:4:2	,, ,,	174.10	,,
33	— naphthoic acid, OH:COOH=1:2	$C_{10}H_6OH.COOH$	188.12	$C_{11}H_8O_3$

Density $H_2O=1$.	Water.	Solubility in— Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	h.v.s.s.	v.s.	v.s.	152		1
				82		2
1.1520/15°	s.	m.	m.	– 21	196.5	3
	h.s.	s.	s.	107	240	4
	c.s.s.	s.	s.	116	subl.	5
1.4835/4°	8 :100/100°	1 :2/15°	s.	156.5		6
1.473/4° 0.843 :100/18.8°			s.	199.8		7
1.468/4°	0.942 :100/20°	s.	s.	215	d.	8
1.1613/25°	1 :15/22°, h.m.	v.s.	v.s.	86	subl.	9
	h.s.	s.	s.	67	300 d.	10
	s.	s.	s.	110		11
				42	225 d.	12
						13
				liq. —17		14
	v.s.	v.s.	v.s.	79	212	15
	v.s.	v.s.	v.s.	72.5—73.5	subl.	16
	1 : 2.85/ 17.5°	s.	s.	80	subl. 50	17
				60—62		18
	v.s.s.	v.s.	v.s.	69.5		19
	v.s.	v.s.	v.s.	159—160		20
	h.s.	s.	s., s. CHCl$_3$	160—162	305—308	21
	c.v.s.s.	s.	s.	70	330	22
	h.s.s.	s.	s.	81.5—82	340	23
						24
	m.	s.		liq.	199	25
	s.	s.		72—73		26
	v.s.	v.s.	v.s.	140.5		27
				34		28
	s.s.	s.	s	110—111		29
	1 : 43/20°	s.	s.	120		30
	i., s. CHCl$_3$	s., s. acetic.	s.s.	151—154		31
	h.s.s.	s.	s.	d. 190	subl	32
	h.s.s.	s.s.	s.s.	186		33

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Hydroxy naphthoic acid, 5:1	$C_{10}H_6OH.COOH$	188.12	$C_{11}H_8O_3$
2	———, 8:1	,, ,,	188.12	,,
3	———, 7:2	,, ,,	188.12	,,
4	———, 2:1	,, ,,	188.12	,,
5	———, 3:2	,, ,,	188.12	,,
6	— nicotinic acid, p	$C_5H_3N(OH)COOH$	139.08	$C_6H_5O_3N$
7	— phenyl acetic acid,o	$HO.C_6H_4.CH_2.COOH$	152.10	$C_8H_8O_3$
8	———, m	,, ,,	152.10	,,
9	———, p	,, ,,	152.10	,,
10	—— ethylamine, p	$OH.C_6H_4.C_2H_4.NH_2$	137.14	$C_8H_{11}ON$
11	—— propiolic acid, p	$OH.C_6H_4.C : C.COOH$	162.09	$C_9H_6O_3$
12	— phthalic acid, COOH : COOH : OH =			
13	1:2:3	$C_6H_3(OH)(COOH)_2$	182.09	$C_8H_6O_5$
14	1:2:4	,, ,,	182.09	,,
15	1:3:2	,, ,, .H_2O	200.11	,,
16	1:3:4	,, ,,	182.09	,,
17	1:3:5	,, ,,	182.09	,,
18	1:4:3	,, ,,	182.09	,,
19	— pyridine, α pyridone	CH⟨CH.C(OH) / CH:CH⟩N	95.08	C_5H_5ON
20	——, β pyridone	CH⟨C(OH).CH / CH:CH⟩N	95.08	,,
21	—, γ pyridone	C(OH)⟨CH:CH / CH:CH⟩N.H_2O	113.10	,,
22	— quinaldine, 8:2	$C_{10}H_9NO$	159.13	$C_{10}H_9ON$
23	——, 6:2	,,	159.13	,,
24	——, 5:2	,,	159.13	,,
25	——, 4:2	,, .$2H_2O$	195.16	,,
26	— quinoline, 8	C_9H_7NO	145.11	C_9H_7ON

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	v.s.			219		1
	s.s.	v s.	v.s.	169		2
	v.s.s.	v.s.s.	v.s.s.	245		3
	v.s.	v.s.s. (abs.)		156 d.		4
	i.	s.s.	s.s.	216		5
	h.s.s.	v.s.s.	v.s.s.	d. 301—302	subl.	6
	s.		s.	137		7
	v.s.	v.s.	v.s.	128.5		8
	h.v.s.	v.s.	v.s.	145		9
	c.s.s.	1 : 10 h.	s. C₆H₆	161—163	175—181 /8mm.	10
	h.s.	s.		192—193	d.	11
						12
	1 : 5/17°	v.s.	v.s.	150		13
	1·32/10°	s.	s.	181		14
	1 : 40/100°	s.	s.	239, an. 243—244		15
	c.v.s.s.	v.s.	s.	305—306		16
	1 : 5.4/100°	s.	s.	288		17
	h.s.s.	s.	s.	subl.		18
	v.s.	v.s.	s.	106—107	280—281	19
	s.	s.		129		20
	1 : 1/15°	s.	v.s.s.	66, an. 148.5		21
	s.s.	h.s.	s.	74	266—267 subl.	22
	v.s.s.	s.	s.	213		23
	i.	h.s	s.	232—234		24
	1 : 100 c.	s.	i.	231		25
	0.48 : 100 /15°	s.	s.s.	75.8	266.6/ 752mm	26

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Hydroxy quinoline, 2	C_9H_7NO	145.11	C_9H_7ON
2	— —, 6	,,	145.11	,,
3	— —, carbostyril	,,	145.11	,,
4	— salicylic acid, see	Dihydroxy benzoic acid		
5	— stearic acid, a	$C_{18}H_{36}O_3$	300.38	$C_{18}H_{36}O_3$
6	— — —, β	,,	300.38	,,
	— toluic acid, $COOH:CH_3:OH =$			
7	2 : 1 : 3	$CH_3.C_6H_3(OH)COOH$	152.10	$C_8H_8O_2$
8	2 : 1 : 6	,, ,,	152.10	,,
9	2 : 1 : 4	,, ,,	152.10	,,
10	2 : 1 : 5	,, ,, $.\frac{1}{2}H_2O$	161.11	,,
11	3 : 1 : 2	,, ,,	152.10	,,
12	3 : 1 : 4	,, ,,	152.10	,,
13	3 : 1 : 5	,, ,,	152.10	,,
14	3 : 1 : 6	,, ,, $.\frac{1}{2}H_2O$	161.11	,,
15	4 : 1 : 2	,, ,,	152.10	,,
16	4 : 1 : 3	,, ,,	152.10	,,
17	Hypogæic acid, physetoleic acid	$C_{15}H_{29}COOH$	254.32	$C_{16}H_{30}O_2$
18	Hypoxanthine	$C_5H_4N_4O$	136.10	$C_5H_4ON_4$
19	Hystazarin, see	Dihydroxy anthraquinone		
20	Imesatine	$C_6H_4 \begin{smallmatrix} C:(NH) \\ \diagdown \quad \diagup \\ NH \end{smallmatrix} CO$	146.11	$C_8H_6ON_2$
21	Indene	$C_6H_4 \begin{smallmatrix} CH \\ \diagup \quad \\ CH_2 \end{smallmatrix} CH$	116.11	C_9H_8
22	Indican	$C_{26}H_{31}NO_{17}$	629.39	$C_{26}H_{31}O_{17}N$
23	Indigotin	$C_6H_4 \begin{smallmatrix} CO \\ \diagdown \quad \diagup \\ NH \end{smallmatrix} C:C \begin{smallmatrix} CO \\ \diagup \quad \diagdown \\ NH \end{smallmatrix} C_6H_4$	262.18	$C_{16}H_{10}O_2N_2$
24	Indin	$C_{16}H_{10}N_2O_2$	262.18	,,
25	Indole	$C_6H_4 \begin{smallmatrix} CH \\ \diagup \quad \\ NH \end{smallmatrix} CH$	117.11	C_8H_7N
26	Indophenine	$C_{12}H_7ONS$	213.19	$C_{12}H_7ONS$

Density H$_2$O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
			s.s.	199—200 d.		1
	h.s.	s.s.	v.s.s.	193—195	>360	2
	h.s.	v.s.	v.s.	199—200	subl.	3
						4
		0.58 : 100 /20°	s.	75		5
				81—81.5		6
	h.s.	v.s.	v.s.	168		7
	h.s.	v.s.	v.s.	183		8
	c.s.	v.s.	v.s.	172		9
	h.s.	v.s.	v.s.	177—178		10
			s. CHCl$_3$	163—164		11
	h.s.	v.s.	v.s.	150		12
	c.s.			208	subl	13
	h.s.	s.	s.	172—175		14
	h.s.	s.	s.	206—207		15
	i.	h.s.	s.	177		16
	i.	s.	s.	33		17
	1 : 300 c h.s.	s.s.	i.		d	18
						19
	i.	h.s.	s.s.			20
1.0059/4				- 2	181.9	21
		s		syrup.	d.	22
1.35	i.	i.	s. aniline.	390—392 d.	subl. 156—158 /0mm.	23
	i.	h.s.s.	s.s.			24
	h.s.	s.	s.	52	253—254	25
	i.	v.s.s.	v.s.s			26

Name	Formula	Formula Weight.	Empirical Formula
1 Indoxyl	$C_6H_4\begin{smallmatrix}C(OH)\\ \\NH\end{smallmatrix}CH$	133.11	C_8H_7ON
2 Indoxylic acid	$C_9H_7NO_3$	177.11	$C_9H_7O_3N$
3 Indoxyl sulphuric acid	$C_8H_7NSO_4$	213.17	$C_8H_7O_4NS$
4 Inosite, see	Dambose		
5 Inulin	$C_{36}H_{62}O_{31}$	990.68	$C_{36}H_{62}O_{31}$
6 Iodo acetic acid	$CH_2I.COOH$	185.95	$C_2H_3O_2I$
7 — acetate, ethyl	$CH_2I.COOC_2H_5$	214.00	$C_4H_7O_2I$
8 — aniline, m	$C_6H_4I.NH_2$	219.01	C_6H_6NI
9 — —, p	,,	219.01	,,
10 — benzene	C_6H_5I	203.99	C_6H_5I
11 — propionic acid, a	$CH_3.CHI.COOH$	199.98	$C_3H_5O_2I$
12 — — —, β	$CH_2I.CH_2COOH$	199.98	,,
13 Iodoform	CHI_3	393.77	CHI_3
14 Iodoso benzene	C_6H_5IO	219.99	C_6H_5OI
15 Iodoxy benzene	$C_6H_5IO_2$	235.99	$C_6H_5O_2I$
16 Ionone	$C_{13}H_{20}O$	192.23	$C_{13}H_{20}O$
17 — semicarbozone, a	$C_{13}H_{20}:N.NH.CO NH_2$	249.28	$C_{14}H_{23}ON_3$
18 — —, β		249.28	
19 Irone	$C_{13}H_{20}O$	192.23	$C_{13}H_{20}O$
20 Isatin	$C_6H_4\begin{smallmatrix}CO\\ \\N\end{smallmatrix}COH$	147.09	$C_8H_5O_2N$
21 — anilide, a	$C_6H_4\begin{smallmatrix}CO\\ \\NH\end{smallmatrix}C:N.C_6H_5$	222.17	$C_{14}H_{10}ON_2$
22 — chloride	$C_6H_4:CO(N):C.Cl$	165.54	C_8H_4ONCl
23 Isatinic acid	$NH_2.C_6H_4.CO.COOH$	165.11	$C_8H_7O_3N$
24 Isatoic anhydride	$C_6H_4\begin{smallmatrix}CO.O\\ \\NH.CO\end{smallmatrix}$	163.09	$C_8H_5O_3N$
25 Isatoxime	$C_6H_4\begin{smallmatrix}C:NOH\\ \\N:C.OH\end{smallmatrix}$	162.11	$C_8H_6O_2N_2$
26 Isatropic acid	$C_9H_8O_2$	148.11	$C_9H_8O_2$
27 Isethionic acid	$C_2H_4(OH)SO_3H$	126.12	$C_2H_6O_4S$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
			s. alk.	85		1
	s.s.				122—123 subl. d.	2
	s.	h s	ı.	d.		3
						4
1.3491	s.s.	s.s.		d. 160		5
				82		6
					178—180	7
	i.	s.		27		8
	i.	s.		64		9
1.833/15°	i.	s.		− 28.5	188.2	10
	v.s.s.			44.5—45.5		11
	h.s.	v.s.	v.s.	85		12
4.008/17°	i.	s.	s.	119	subl. d.	13
	h.s.	s.	i.	105—106 d.		14
	h.s.			167		15
0.935/20°		s.	s., s. C_6H_6	126—128	/12mm.	16
		v.s.s.ligroin		117—118		17
				148—149		18
0.939/20°	v.s.s.	s.	s.	liq.	144/16mm.	19
	h.s.	s.	s.	200—201	subl.	20
		h.s.	s.	126		21
	i.	s.	s. to B.	d. 180		22
	s.s.			d.		23
		s.e	s s.	d. 230		24
	v.s.s.	s.		202		25
	h.v.s.s.	s.s.	i.	237—237.5		26
	v.s.			syrup.		27

Name.	Formula	Formula Weight.	Empirical Formula.
1 Iso-anthraflavic acid, see Dihydroxy anthraquinone			
2 Iso-cholesterin	$C_{26}H_{43}OH$	372.48	$C_{26}H_{44}O$
3 — — benzoate	$C_{26}H_{43}.O.C_7H_5O$	476.55	$C_{32}H_{48}O_2$
4 — cinchomeronic acid	$C_7H_5NO_4.H_2O$	185.11	$C_7H_5O_5N$
5 — citric acid	$C_6H_8O_7$	192.09	$C_6H_8O_7$
6 — coumarin	$C_6H_4 \begin{smallmatrix} CH:CH \\ \mid \\ CO.O \end{smallmatrix}$	146.09	$C_9H_6O_2$
7 — crotonic acid	$CH_2:CH.CH_2.COOH$	86.07	$C_4H_6O_2$
8 — cymene	$C_{10}H_{14}$	134.16	$C_{10}H_{14}$
9 — dulcitol, rhamnose	$CH_3.(CHOH)_4.CHO.H_2O$	182.14	$C_6H_{12}O_5$
10 — durene, 1:2:3:5	$C_6H_2(CH_3)_4$	134.16	$C_{10}H_{14}$
11 — eugenol, 4:3:1	$C_6H_3(OH)(OCH_3)OH:CH.CH_3$	164.15	$C_{10}H_{12}O_2$
12 — ferulic acid	$C_7H_7O_2.C_2H_2.COOH$	194.13	$C_{10}H_{10}O_4$
13 — glucosamine	$C_6H_{11}O_5(NH_2)$	179.14	$C_6H_{13}O_5N$
14 — hydrobenzoin	$C_6H_5.CHOH.CHOH.C_6H_5$	214.18	$C_{14}H_{14}O_2$
15 — naphthazarin, 2:3	$C_{10}H_4O_2(OH)_2$	190.10	$C_{10}H_6O_4$
16 — nitroso acetone	$CH_3.CO.CH:N.OH$	87.09	$C_3H_5O_2N$
17 — — acetophenone	$C_8H_7O_2N$	149.10	$C_8H_7O_2N$
18 — orcinol, see	Dihydroxy toluene		
19 — phloretinic acid	$C_9H_{10}O_3$	166.13	$C_9H_{10}O_3$
20 — quinoline	C_9H_7N	129.11	C_9H_7N
21 — vanillin, 1:4:3	$C_6H_3(CHO)(OCH_3)OH$	152.10	$C_8H_8O_3$
22 Isoprene	C_5H_8	68.09	C_5H_8
23 Itaconic acid	$CH_2:C(COOH)CH_2.COOH$	130.07	$C_5H_6O_4$
24 Itamalic acid	$CH_2OH.CH(COOH)CH_2.COOH$	148.09	$C_5H_8O_5$
25 Juglon, see	Hydroxy naphthoquinone		
26 Kairoline, N. methyl tetra hydroquinoline	$C_9H_{10}N.CH_3$	147.16	$C_{10}H_{13}N$
27 Ketazine	$(CH_3)_2:C:N_2:C:(CH_3)_2$	112.15	$C_6H_{12}N_2$
28 Keto-butyric acid, pro pionylformic acid	$CH_3.CH_2.CO.COOH$	102.07	$C_4H_6O_3$

Note:—Many *iso* compounds may

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
						1
		s.s.	s.	137—138		2
		s.	s.	190—191		3
	v.s.s.	v.s.s.	v.s.s.	236	subl. d.	4
	s.					5
	i.	v.s.	s., s. C_6H_6	47	285—286 /219mm	6
1.018/0°	1:35/19°			155	171.9	7
0.862/20°				− 20 liq	171—172	8
1.4708/20°	57.11 : 100/19°	54 : 10°		92—93		9
		s.	s.		195	10
1.08/16°	v.s.s.	s.	s.		258—262	11
	h.s.	s.	s.	228		12
		s.	i.			13
	s.s.	v.s.	v.s.	121		14
	h.s.s.	s.	s.	276		15
	v.s.		v.s.	65	subl.	16
	c.s.s.			126		17
						18
	s.			128—129		19
1.1025/20°		s.		24.6	240/730mm.	20
1.196	h.s.	s.	s.	116	179/15mm.	21
0.6867/16.5°					34.0/762mm.	22
1.573-1.632	1:17/10°	i : 4 (88%)	s.	161	d.	23
	del.	s.	s.	64	d.	24
						25
1.022/20°		v.s.	s.s.		242—244 /720mm.	26
0.836				31.5—32	131	27
1.2/17°					74—78/ 25mm.	28

be found under the corresponding normal compounds.

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Keto pyrrolidine	$CH_2.CO$ $\big\rangle NH$ $CH_2.CH_2$	85.09	C_4H_7ON
2 Kynuric acid, 1 : 2	$C_6H_4(COOH).NH.CO.COOH$	209.11	$C_9H_7O_5N$
3 Lactamide	$CH_3.CHOH.CONH_2$	89.09	$C_3H_7O_2N$
4 Lactic acid, $d., l.$	$CH_3.CHOH.COOH$	90.06	$C_3H_6O_3$
5 — —, para, $d.$	„ „	90.06	„
6 Lactate, ethyl	$CH_3.CHOH.COOC_2H_5$	118.11	$C_5H_{10}O_3$
7 Lactic anhydride, a	$CH_3.CHOH.COO$	162.11	$C_6H_{10}O_5$
8 Lactide, i	$COOH.(CH_3)CH$ $OH(CH_3).CO$ $O \big\rangle O$ $CO.CH(CH_3)$	144.09	$C_6H_8O_4$
9 Lactobionic acid	$C_{12}H_{22}O_{12}$	358.24	$C_{12}H_{22}O_{12}$
10 Lactose, see	Milk sugar		
11 Lactyl urea	$CO\big\langle \begin{array}{l} NH.CH.CH_3 \\ NH.CO \end{array}$	132.11	$C_4H_6O_2N_2$
12 Lævulin	$(C_6H_{10}O_5)x$	(162.11)	
13 Lævulinic acid	$CH_3.CO.CH_2.CH_2.COOH$	144.09	$C_5H_8O_3$
14 Lævulose, fructose	$C_6H_{12}O_6$	196.13	$C_6H_{12}O_6$
15 Lauric acid	$C_{11}H_{23}COOH$	200.25	$C_{12}H_{24}O_2$
16 Lead tetraethyl	$Pb(C_2H_5)_4$	324.40	$C_8H_{20}Pb$
17 — tetramethyl	$Pb(CH_3)_4$	267.32	$C_4H_{12}Pb$
18 — triethyl	$Pb(C_2H_5)_3$	294.95	$C_6H_{15}Pb$
19 Lecithin	$C_{42}H_{84}NPO_9$	777.93	$C_{42}H_{84}O_9NP$
20 Lepidine, 1 : 3	$C_9H_6N.CH_3$	143.13	$C_{10}H_9N$
21 Leucaniline	$HO\big\langle \begin{array}{l} (C_6H_4.NH_2)_2 \\ C_6H_3(CH_3)NH_2 \end{array}$	303.30	$C_{20}H_{21}N_3$
22 Leucaurine	$CH(C_6H_4OH)_3$	292.22	$C_{19}H_{16}O_3$
23 Leucinic acid	$C_5H_{10}(OH)COOH$	132.13	$C_6H_{12}O_3$
24 Leuconic acid	$C_5H_8O_9$	212.09	$C_5H_8O_9$
25 Lichenine	$(C_6H_{10}O_5)x$	(162.11)	
26 Lignoceric acid	$C_{24}H_{48}O_2$	368.50	$C_{24}H_{48}O_2$
27 Limonene, $d.$	$CH_3.C\big\langle \begin{array}{l} CH.CH_2 \\ CH_2.CH_2 \end{array}\big\rangle OH.C\big\langle \begin{array}{l} CH_3 \\ CH_3 \end{array}$	136.18	$C_{10}H_{16}$
28 — r	„ „	136.18	„

Density H$_2$O=1.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C	B.P. °C	
				24.6	245	1
	v.s.s.	h.s.	s.s.	257		2
	v.s.	s.		74		3
1.2485/15°	del.	m.	s.	18	119/12mm	4
	m.	m.	s.	25—26	d.	5
1.055./0				liq.	154.5	6
	s.s.	s.	s.	d. 250—260		7
	s.s.	c.v.s.s.		125	255	8
	v.s.	s.s.	l.	100 : lactone		9
						10
	s.	s.	s.s.	145		11
	s.	v.s.s. (abs.)	i.	d.		12
1.1395/20°	m.	s.	s.	32.5—33	250—253	13
	s.	s.	s.	95	d. 100	14
0.883/20°	i.	s.	s.	43.6	225/100	15
1.62	i.			liq.	152	16
2.034/0°				liq.	110	17
1.471/10°	i.			liq.	d.	18
	i.	s.	s.	d.		19
1.0862/20°	s.s.	m.	m.	liq.	265.5/746.7	20
	h.s.s.	v.s.	s.s.	100		21
	s.s.	s.	s. acetic.			22
	s.	s.	s.	76—77 rac. 81—82 act.		23
	v.s.	s.s.	v.s.s.			24
	h.s.	i.	i.			25
	s.CS$_2$, C$_6$H$_6$	s.	s.	80—81		26
0.853/10°			s. CHCl$_3$		177.6—178	27
0.846/20°		s.	s. CHCl$_3$		175—176	28

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Linalool	$(CH_3)_2:C:CH.(CH_2)_2.$ $C(CH_3).OH.CH:CH_2$	154.19	$C_{10}H_{18}O$
2 Linoleic acid	$C_{18}H_{32}O_2$	280.35	$C_{18}H_{32}O_2$
3 Lophine	$C_{21}H_{16}N_2$	298.27	$C_{21}H_{16}N_2$
4 Luteolin	$(OH)_2 \quad O.C.C_6H_3(OH)_2$ $C_6H_2 \quad \| \quad CO.CH$	286.16	$C_{15}H_{10}O_6$
5 Lutidine, 2:6	$C_5H_3N(CH_3)_2$	107.12	C_7H_9N
6 Lutidine acid, see	Pyridine dicarboxylic acid		
7 Lysine, see	Amino caproic acid		
8 Maclurin	$CO \diagup^{C_6H_2(OH)_3}_{\diagdown C_6H_3(OH)_2}$	280.17	$C_{13}H_{10}O_6$
9 Maleic acid	$C_2H_2(COOH)_2$	116.05	$C_4H_4O_4$
10 — anhydride	$C_2H_2:(CO):O$	98.04	$C_4H_2O_3$
11 Malic acid, l	$COOH.CHOH.CH_2.COOH$	134.07	$C_4H_6O_5$
12 Malic amide	$C_2H_3(OH)(CO.NH_2)_2$	132.10	$C_4H_8O_3N_2$
13 Malate, ethyl	$CH_2.COOC_2H_5$ $CHOH.COOC_2H_5$	190.15	$C_8H_{14}O_5$
14 Malonic acid	$CH_2(COOH)_2$	104.05	$C_3H_4O_4$
15 Malonate, diethyl	$CH_2(COOC_2H_5)_2$	160.13	$C_7H_{12}O_4$
16 Malonyl chloride	$CH_2:(COCl)_2$	152.95	$C_3H_2O_2Cl_2$
17 — urea	$CO:(NH.CO)_2:CH_2$	128.09	$C_4H_4O_3N_2$
18 Maltose	$C_{12}H_{22}O_{11}.H_2O$	360.26	$C_{12}H_{24}O_{12}$
19 Mandelic acid	$C_6H_5.CHOH.COOH$	152.10	$C_8H_8O_3$
20 Mannitan, amorph	$C_6H_{12}O_5$	164.13	$C_6H_{12}O_5$
21 ——, cryst	„	164.13	„
22 Mannitol, d	$C_6H_8(OH)_6$	182.14	$C_6H_{14}O_6$
23 — nitrate	$C_6H_8(ONO_2)_6$	452.15	$C_6H_8O_{18}N_6$
24 Manno-heptose d	$C_6H_7(OH)_6CHO$	210.15	$C_7H_{14}O_7$
25 — octite, d	$C_8H_{18}O_8$	242.18	$C_8H_{18}O_8$
26 Mannonic acid, $d, l, i.$	$C_5H_7(OH)_5COOH$	196.13	$C_6H_{12}O_7$
27 —— lactone, d	$C_6H_{10}O_6$	178.11	$C_6H_{10}O_6$
28 Mannose, $d.$ (Seminose)	$C_6H_{12}O_6$	180.13	$C_6H_{12}O_6$
29 Margaric acid	$C_{16}H_{33}COOH$	270.36	$C_{17}H_{34}O_2$
30 Meconic acid	$C_7H_4O_7.3H_2O$	254.12	$C_7H_{10}O_{10}$
31 Meconine	$C_{10}H_{10}O_4$	194.13	$C_{10}H_{10}O_4$
32 Melam	$C_6H_9N_{11}$	235.21	$C_6H_9N_{11}$

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.870/15°				liq.	199—200	1
0.9206/14°				oil.		2
	i.	ь s.	s.s.	270		3
	v.s.s	1 : 37	s.s.	328—329.5		4
0.946/0°	1 : 3.5			liq	142--143	5
						6
						7
	h.s.	s.	s.	200		8
1.590	1 : 2/10°	s.	s.	130--130.5	d.	9
0.9339/19.2°				50—51	196	10
1.559/4°	v.s.	v.s.		100	d.	11
	1 : 12/8°	i.		170		12
1.1210/21°				liq.	149—25mm.	13
	v.s.	s.	s.	132	d.	14
1.061/15°				- 49.9	198—198.6	15
		-			47/13mm.	16
	h.s.			d.		17
1.540/17.5°	s.	s.s.				18
1.36/4°	15.97 : 100/20°	s.	s.	inact. 118.5, l. 133		19
	s.	v.s. (abs.)	i.	100		20
	1 : 4/15°	s.s.				21
1.521	27 : 100/25°	h.s.	i.	165	278/1mm	22
1.604	i.	h.s.	s.	108	expl.	23
	s.	s.s.		134—135		24
	h.s.s.			258		25
	s.			FORMS LACTONE		26
				149—153		27
	248 : 100/17°	v.s.s. abs.	i.	123		28
				59.5	227/100	29
	.	s.	s.			30
	1 : 22/100°			102	subl.	31
	i.	s.h. KOH.				32

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Melene	$C_{30}H_{60}$	420.63	$C_{30}H_{60}$
2	Melilotic acid	$C_6H_4(OH)CH_2.CH_2.COOH$	166.13	$C_9H_{10}O_3$
3	Melissic acid	$C_{29}H_{59}COOH$	452.63	$C_{30}H_{60}O_2$
4	Melissyl alcohol	$C_{30}H_{61}OH$	438.65	$C_{30}H_{62}O$
5	Melitriose, see	Raffinose		
6	Mellitic acid	$C_6(COOH)_6$	342.11	$C_{12}H_6O_{12}$
7	Mellophanic acid	$C_6H_2(COOH)_4 (1:2:3:5)$	254.10	$C_{10}H_6O_8$
8	Menthene	$C_{10}H_{18}$	138.19	$C_{10}H_{18}$
9	Menthol, d	$C_{10}H_{19}(OH)$	156.20	$C_{10}H_{20}O$
10	Menthone, d	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
11	Mercury di-ethyl	$Hg(C_2H_5)_2$	258.70	$C_4H_{10}Hg$
12	— dimethyl	$Hg(CH_3)_2$	230.66	C_2H_6Hg
13	— dinaphthyl, 1	$Hg(C_{10}H_7)_2$	454.81	$C_{20}H_{14}Hg$
14	— —, 2	,,	454.81	,,
15	— diphenyl	$Hg(C_6H_5)_2$	354.74	$C_{12}H_{10}Hg$
16	— mercaptan	$Hg_2(C_2H_5)_2S$	491.36	$C_4H_{10}SHg_2$
17	Mesaconic acid	$(CH_3)(COOH)C:CH.COOH$	130.07	$C_5H_6O_4$
18	Mesidine, 1:3:5:2	$C_6H_2(CH_3)_3NH_2$	135.16	$C_9H_{13}N$
19	Mesitol	$C_6H_2(CH_3)_3OH$	136.14	$C_9H_{12}O$
20	Mesitylene, 1:3:5	$C_6H_3(CH_3)_3$	120.14	C_9H_{12}
21	Mesitylenic acid	$C_6H_3(CH_3)_2COOH$	150.13	$C_9H_{10}O_2$
22	Mesityl oxide	$(CH_3)_2:C:CH.COCH_3$	98.11	$C_6H_{10}O$
23	Mesorcin	$C_6H_3(CH_3)(OH)_2$	152.14	$C_8H_{12}O_2$
24	Mesoxalic acid	$(COOH)_2C(OH)_2$	136.05	$C_3H_4O_6$
25	Metacetone	$C_5H_{10}O$	98.11	$C_6H_{10}O$
26	Metacroleïn	$C_9H_{12}O$	136.14	$C_9H_{12}O$
27	Metaldehyde	$(CH_3.CHO)_3$	132.12	$C_6H_{12}O_3$
28	Metanilic acid, see	Amino benzene sulphonic acid		
29	Metastyroline	$(C_8H_8)x$	(104.10)	
30	Methacrylic acid	$CH_2:C:(CH_3)COOH$	86.07	$C_4H_6O_2$
31	Methane	CH_4	16.04	CH_4
32	Methoxy pyridine, γ	$C_2H_2\big\langle\begin{smallmatrix}C & -OCH_3\\ N\end{smallmatrix}\big\rangle C_2H_2$	109.10	C_6H_7ON
33	— quinoline, γ	$C_9H_6N(OCH_3)$	159.13	$C_{10}H_9ON$
34	Methyl acetanilide	$C_6H_5.N(CH_3).CO.CH_3$	149.14	$C_9H_{11}ON$
35	— acetoacetic acid, ethyl ester	$CH_3CO.CH(CH_3)COOC_2H_5$	144.13	$C_7H_{12}O_3$

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C	B.P. °C	
0.89		3.6 : 100 h.		62		1
	1 : 20/18°	s.	s.	82—83	d.	2
		h.s.	s.s.	90		3
				88		4
						5
	v.s.	s.		286—288 under press.		6
	s.			238		7
0.837/0°				167.4		8
0.890/15°	s.s.	s.	s.	42	212	9
0.9126/0°	m. $CHCl_3$	m.	m. C_6H_6	liq.	206-208	10
2.44	i.	s.s.	s.	liq.	159	11
3.069	i.			liq.	96	12
1.929	S.CS_2	h.s.s	s. $CHCl_3$	243		13
				238		14
2.32	S.CS_2	h.s.s	s. $CHCl_3$, C_6H_6	120	300 d	15
				82	d.	16
	2.7 : 100/18°	s.		202	d.	17
0.9633				liq.	227	18
		s.	s.	68—69	219.5	19
0.8694/10°	i.	s.	s.	- 57.5	164.5	20
	h.s.s.	v.s.		165—166	subl.	21
0.8578/20°	i.	m.		liq.	131—132	22
	c.s.s.	v.s.	v.s.	149—150	275	23
	s.	s.	s.	115		24
>H_2O	i.				84	25
	h.v.s.s.	s.	s.	50	170	26
	l.	s.s.	s.s.	246.2		27
						28
1.054/13°	i.	i.	v.s.s.		320 d.	29
1.0153/20°	v.s.			16	160.5	30
	0.054 : 1 vol.			- 184	- 164	31
	s.			liq.	191—738mm	32
1.665/0°		s.		31	241	33
	i.	s.		101	237	34
1.009/6°					189.7	35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Methyl acetoacetic acid, methyl ester	$CH_3CO.CH(CH_3)COOCH_3$	130.11	$C_6H_{10}O_3$
2	— acetophenone, o	$CH_3.C_6H_4.COCH_3$	134.12	$C_9H_{10}O$
3	— —, m	,, ,,	134.12	,,
4	— —, p	,, ,,	134.12	,,
5	— acridine, 1	$C_6H_4 \Big\langle \begin{matrix} C & -CH_3 \\ \mid & \\ N \end{matrix} \Big\rangle C_6H_4$	193.17	$C_{14}H_{11}N$
6	— —, 3	$C_{13}H_8N.CH_3$	193.17	,
7	— —, 5	,, ,,	193.17	,,
8	— alcohol	CH_3OH	32.04	CH_4O
9	— alizarin	$C_6H_4 : (CO)_2 : C_6H(CH_3) \; (OH)_2$	254.16	$C_{15}H_{10}O_4$
10	— amine	$CH_3.NH_2$	31.06	CH_5N
11	— amino acetic acid	$CH_2(NH.CH_3)COOH$	89.08	$C_3H_7O_2N$
12	— aniline	$C_6H_5.NH.CH_3$	107.12	C_7H_9N
13	— anthracene, 1	$C_6H_4 : (CO)_2 : C_6H_3.CH_3$	192.17	$C_{15}H_{12}$
14	— —, 2	,, ,,	192.17	,,
15	— anthraquinone, 1	$C_{14}H_7O_2.CH_3$	222.16	$C_{15}H_{10}O_2$
16	— —, 2	,, ,,	222.16	,,
17	— arsenic acid	$CH_3.HAsO_2(OH)$	140.01	CH_5O_3As
18	— — oxide	$AsO.CH_3$	105.99	CH_3OAs
19	— — dichloride	$AsCl_2.CH_3$	160.91	CH_3Cl_2As
20	— benzothiazole	$C_6H_4 \Big\langle \begin{matrix} N \\ \\ S \end{matrix} \Big\rangle C.CH_3$	149.16	C_8H_7NS
21	— benzoxazole	$C_6H_4 \Big\langle \begin{matrix} N \\ \\ O \end{matrix} \Big\rangle C.CH_3$	133.10	C_8H_7ON
22	— borate	$(CH_3)_3BO_3$	104.0	$C_3H_9O_3B$
23	— bromide	CH_3Br	94.95	CH_3Br
24	— carbylamine	$CH_3.NC$	41.04	C_2H_3N
25	— chloride	CH_3Cl	50.49	CH_3Cl
26	— chloroform	$CCl_3.CH_3$	133.41	$C_2H_3Cl_3$
27	— coumarin, α	$C_6H_4 \Big\langle \begin{matrix} C(CH_3):CH \\ \mid \\ O—CO \end{matrix}$	160.11	$C_{10}H_8O_2$
28	— —, β	$C_9H_5O_2.CH_3$	160.11	,,
29	— cyanate	$N : C.OCH_3$	57.04	C_2H_3ON
30	— —, iso	$CO : N.CH_3$	57.04	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
					63.8—64/11mm.	1
1.026/20°					211/745mm. (corr.)	2
0.986/20°					221/745mm. (corr.)	3
1.021/0°		m.	m.		224.5/745mm. (corr.)	4
	s. C₆H₆	v.s.	v.s.	88		5
				125—126		6
				114		7
0.8102/0°	m.	m.	m.	− 97.8	64.7	8
	s. acetone	s.	s.	232—233	subl. 200	9
		s.				
9.699/−11°	1150 : 1 vol.			gas.	− 6.7/75mm.	10
	v.s.	s.s.		130	250 d.	11
0.9863/20°				− 80	193.8	12
	s. CS₂	s.	s. C₆H₆	85—86		13
				199—200		14
		s.	s.	161—163	subl.	15
				177		16
	s.	s.		161		17
				95	d.	18
				liq.	133	19
	i.	s.		liq.	238	20
	i.	s.		liq.	201	21
0.94/0°					65—66	22
1.732/0°	s.s.	s.			4.5	23
0.7557	1 : 10	35 : 1		− 45	59.6	24
0.9915/−24°	s.s.	s.	s. acetic.	− 103.6	− 24.1	25
1.3657					74	26
		s.	s. C₆H₆	90		27
				81—82		28
	h.s.	s.				29
	i.	s.			45	30

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Methyl cyanide	CH_3CN	41.04	C_2H_3N
2 — cyclo hexane, see	Hexa hydro toluene		
3 — diphenylamine	$(C_6H_5)_2:N.CH_3$	183.18	$C_{13}H_{13}N$
4 — ether	$CH_3.O.CH_3$	46.06	C_2H_6O
5 — furfurane, sylvan	$C_4H_3O.CH_3$	82.07	C_5H_6O
6 — furfurol, 5:2	$C_5H_3O_2.CH_3$	110.08	$C_6H_6O_2$
7 — glycocyamide, see	Creatine		
8 — glycocyamidine, see	Creatinine		
9 — glyoxalin	$C_3H_3N_2.CH_3$	82.09	$C_4H_6N_2$
10 — guaiacol	$C_6H_3(OH)(OCH_3)CH_3$	138.12	$C_8H_{10}O_2$
11 — hydantoin, 1:2:4	$C_4H_5N_2O_2$	114.09	$C_4H_6O_2N_2$
12 — hydrazine	$CH_3.NH.NH_2$	46.07	CH_6N_2
13 — hydroxylamine, β	$CH_3.NH.OH$	47.06	CH_5ON
14 — indole, N	$C_8H_5N.CH_3$	131.12	C_9H_9N
15 — —, α	$CH_3.C_8H_5NH$	131.12	,,
16 — —, β	,, ,,	131.12	,,
17 — iodide	CH_3I	141.05	CH_3I
18 — isatin	$C_8H_4O_2N(CH_3)$	161.11	$C_9H_7O_2N$
19 — —, pseudo	$C_8H_4ON(OCH_3)$	161.11	,,
20 — mercaptan	$CH_3.SH$	48.10	CH_4S
21 — naphthalene, 1	$C_{10}H_7.CH_3$	142.14	$C_{11}H_{10}$
22 — —, 2	,, ,,	142.14	,,
23 — naphthylamine, 1	$C_{10}H_7.NH.CH_3$	157.15	$C_{11}H_{11}N$
24 — naphthyl ether, α	$C_{10}H_7.O.CH_3$	158.14	$C_{11}H_{10}O$
25 — —, β	,, ,,	158.14	,,
26 — nitrate	$CH_3.NO_3$	77.04	CH_3O_3N
27 — nitrite	CH_3NO_2	61.04	CH_3O_2N
28 — nitrolic acid	$CH(NO_2)NOH$	90.04	$CH_3O_3N_2$
29 — nonyl ketone	$CH_3.CO.C_9H_{19}$	170.23	$C_{11}H_{22}O$
30 — phenazine	$C_6H_4:N_2:C_6H_3.CH_3$	194.17	$C_{13}H_{10}N_2$
31 — phosphate	$CH_3.PO_2(OH)_2$	112.09	CH_5O_4P
32 — phosphine	$CH_3.PH_2$	48.09	CH_5P
33 — piperidine, see	Pipecoline		
34 — propyl benzene, o	$CH_3.C_6H_4.C_3H_7$	134.16	$C_{10}H_{14}$
35 — —, m	,, ,,	134.16	,,
36 — —, p	,, ,,	134.16	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.8052/0°	m.	s.	s.	- 44.4	81.6	1
						2
1.0476/2/°	s.			liq.	282	3
	37 : 1 vol.	s.	600 : 1 H₂SO₄	- 138.4	- 23.7	4
0.887					63—63.5	5
1.1087/18°	1 : 30	s.			184—186	6
						7
						8
1.036/10°	s.			- 6	197—199	9
1.1534/0°	1 : 60/15° by vol.	m.	m.	liq.	219	10
	s.	s.		156	subl.	11
		m.	m.		87/745mm.	12
	v.s.	v.s.		42	62.5/15mm.	13
1.0707/0°	i.	s.	s.		240—241/720mm	14
	h.s.	v.s.s.	v.s.s.	59	272/750mm.	15
	s.s.	s.	i.	95	265—266/755mm.	16
2.2852/15°	1 : 125/ 15° by vol.	s.		- 64.4	42.3	17
	c.s.s.	s. alk.	s. h. HCl	184		18
	s.s.			134		19
<H₂O	d.	s.	s.	liq.	5.8/752mm.	20
1.0287/12°		s.	s.	liq.	240—242	21
		s.s		32.5	243—245	22
	s.CS₂	s.	s.		290—293	23
1.0974/15°				liq.	265	24
	s.s.	s.s.	v.s.	75	271	25
1.2322/5°	s.s.			liq.	65 expl.	26
0.991/15°				gas.	- 12	27
	s.		s.	64		28
0.8295/17.5°				15	232	29
	h.s.s.	s.s.	v.s.	117	d. 350	30
				105		31
	s.s.	v.s.	70 :1 vol.	gas	- 14/758.5	32
						33
	i.	s.		liq.	181—182	34
0.863/16°	i.	s.		liq.	176—177.5	35
0.8682/0°	i.	s.			183—184	36

Name.	Formula.	Formula Weight.	Empirical Formula
1 Methyl *iso* propyl benzene, *m*	$CH_3.C_6H_4.CH:(CH_3)_2$	134.16	$C_{10}H_{14}$
2 —— —, *p*	,, ,,	134.16	,,
3 — propyl ketone	$CH_3.CO.CH_2CH_2.CH_3$	86.10	$C_5H_{10}O$
4 — *iso* propyl ketone	$CH_3.CO.CH(CH_3)_2$	86.10	,,
5 — *iso* propyl cyclo hexane, see Hexa hydro cymene			
6 — pyrogallol, 1:3:4:5	$C_6H_2(CH_3)(OH)_3$	140.10	$C_7H_8O_3$
7 — pyrrole, 2	$C_4H_3(CH_3)NH$	81.09	C_5H_7N
8 —— ; 3	,,	81.09	
9 — sulphate	$CH_3.O.SO_2.OH$	112.10	CH_4O_4S
10 — sulphide	$(CH_3)_2S$	62.12	C_2H_6S
11 — sulphonic acid	$CH_3.SO_3H$	96.10	CH_4O_3S
-tetra hydro quinoline, see Kairoline			
12 — thiocarbamide	$CS(NH_2)(NH.CH_3)$	90.14	$C_2H_6N_2S$
13 — thiocyanate, *iso*	$CH_3.NCS$	73.10	C_2H_3NS
14 — toluidine, *o*	$CH_3.C_6H_4.NH.CH_3$	121.14	$C_8H_{11}N$
15 —— —, *m*	,, ,,	121.14	,,
16 —— —, *p*	,, ,,	121.14	,,
17 — uracil	$CO\begin{array}{l} \diagup NH\text{——}C.CH_2 \\ \ \ \ \ \ \ \ \ \ \ \| \\ \diagdown NH.CO.CH \end{array}$	126.09	$C_5H_6O_2N_2$
18 — urea	$NH_2.CO.NH.CH_3$	74.08	$C_2H_6ON_2$
19 — uric acid	$C_6H_6N_4O_3.1\tfrac{1}{2}H_2O$	209.15	$C_6H_6N_4O_3$
20 Methylal	$H.CH(OCH_3)_2$	76.08	$C_3H_8O_2$
21 Methylene bromide	CH_2Br_2	173.86	CH_2Br_2
22 — chloride	CH_2Cl_2	84.94	CH_2Cl_2
23 — disulphonic acid	$CH_2(SO_3H)_2$	176.16	$CH_4O_6S_2$
24 — iodide	CH_2I_2	267.86	CH_2I_2
25 Milk sugar, lactose	$C_{12}H_{22}O_{11}.2H_2O$	378.27	$C_{12}H_{22}O_{11}$
26 Mono acetin	$C_3H_5(OH)_2O.COOH_3$	134.11	$C_5H_{10}O_4$
27 — thioglycerin, see Glycerin mercaptan			
28 Morin	$C_{15}H_{10}O_7$	302.16	$C_{15}H_{10}O_7$
29 Mucic acid	$C_4H_4(OH)_4(COOH)_2$	210.11	$C_6H_{10}O_8$
30 Muconic acid	$C_6H_6O_4$	142.08	$C_6H_6O_4$
31 Murexide	$C_8H_4O_6N_5.NH_4.H_2O$	302.18	$C_8H_8O_6N_6$
32 Myristic acid	$C_{13}H_{27}.COOH$	228.31	$C_{14}H_{28}O_2$
33 Myristone	$(C_{13}H_{27})_2:CO$	394.57	$C_{27}H_{54}O$

Density H₂O=1.	Solubility in — Water.	Alcohol.	Ether.	M.P. °C	B.P. °C	
0.865/16°	i.	s.		− 25	175—176	1
0.87226/0°	i.	s.		− 73.5	175	2
0.8124/15°	v.s.s.			F.Pt. − 83.5	102	3
0.815/15°					93—94/752.5mm	4
						5
				129		6
					147—148/750	7
					142—143/742	8
	v.s.	s.	an. m.	− 30 liq.		9
0.845/21°				liq.	37.5	10
				d. 130		11
	s.	s.	s.s.	118		12
1.069/37°					119	13
0.973/15°					206	14
					206—207	15
					209—211/761mm	16
					(corr.)	
	s.s.	s.s.	v.s.s.	320 d.		17
	v.s.	v.s.	v.s.	98		18
	1 : 2050 h.	s.s.		360 d.		19
0.855/18°	1 : 3			S.P.—104.8	42.3	20
2.4985/15°				liq.	98.5/756	21
1.3778/0°	i.			S.P.—96.7	41.6	22
	v.del.					23
3.3326/15°				5.7	180 d.	24
1.525/4°	17 : 100/10°	v.s.s.	i.	203.5	d. 203	25
1.2	s.s.			liq.	130—132	26
					/2—3mm	27
	1 : 4000	s.	s.	285		28
	1 : 300/14°	i.		224		29
	1 : 5000	h.s.	s. acetic.	272 d.		30
	h.s.	i.				31
	s.s.	s.	s.	53.8	248/100mm	32
0.8013/76.3~		s.		75		33

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Name.	Formula.	Formula Weight.	Empirical Formula.
1 Naphthalene	$C_{10}H_8$	128.11	$C_{10}H_8$
2 — dicarboxylic acid	$C_{10}H_6(COOH)_2$ (1:5)	216.12	$C_{12}H_8O_4$
3 ———, 1:8	,, ,,	216.12	,,
4 — sulphonic acid, α	$C_{10}H_7(SO_5H).H_2O$	226.19	$C_{10}H_8O_3S$
5 ———, β	,, ,, .H_2O	226.19	,,
6 Naphthalic acid	$C_{10}H_6O_3$	174.12	$C_{10}H_6O_3$
7 Naphthazarin	$C_{10}H_4O_2(OH)_2$	190.10	$C_{10}H_6O_4$
8 Naphthazine	$C_{10}H_6.N_2.C_{10}H_6$	280.22	$C_{20}H_{12}N_2$
9 Naphthionic acid, 1:4	$C_{10}H_6(NH_2)SO_3H.\frac{1}{2}H_2O$	232.20	$C_{10}H_9O_3NS$
10 Naphthoic acid, α	$C_{10}H_7.COOH$	172.12	$C_{11}H_8O_2$
11 ——, β	,,	172.12	,,
12 — aldehyde, α	$C_{10}H_7.CHO$	156.12	$C_{11}H_8O$
13 ——, β	,,	156.12	,,
14 Naphthol, α	$C_{10}H_7.OH$	144.11	$C_{10}H_8O$
15 —, β	,,	144.11	,,
16 — sulphonic acid, 1:4	$C_{10}H_6(OH)SO_3H$	224.17	$C_{10}H_8O_4S$
17 ———, 1:5	,, ,,	224.17	,,
18 ———, 1:8	,, ,, .(H_2O)	224.17	,,
19 ———, 1:2	,, ,,	224.17	,,
20 Naphtho nitrile, α	$C_{10}H_7CN$	153.12	$C_{11}H_7N$
21 ——, β	,,	153.12	,,
22 — phenazine, $\alpha\beta$	$C_{10}H_6:N_2:C_6H_4$	230.18	$C_{16}H_{10}N_2$
23 —— $\beta\beta$	,, ,,	230.18	,,
24 — quinaldine, α	$C_{13}H_8N.CH_3$ (2)	193.17	$C_{14}H_{11}N$
25 ——, β	,, ,, (3)	193.17	,,
26 — quinoline, α	$C_{13}H_9N$	179.15	$C_{13}H_9N$
27 ——, β	,,	179.15	,,
28 — quinone, 1:4	$C_{10}H_6O_2$	158.10	$C_{10}H_6O_2$
29 ——, 1:2	,,	158.10	,,
30 — sultone	$C_{10}H_6{<}^{SO_2}_{O}$	206.16	$C_{10}H_6O_3S$
31 Naphthylamine, α	$C_{10}H_7.NH_2$	143.13	$C_{10}H_9N$
32 —, β	,,	143.13	,,
33 Naphthylene diamine, 1:2	$C_{10}H_6(NH_2)_2$	158.15	$C_{10}H_{10}N_2$
34 ——, 1:5	,, ,,	158.15	,,
35 ——, 1:8	,, ,,	158.15	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
{ 1.145/4° 0.9673/95°	i.	5.29 : 100 /15°	v.s.	80.1	217.96	1
		h.s. (dil.)		>286		2
		v.s.s. C_6H_6		d.		3
	v.s.	s.	s.s.	85—90		4
				124—125		5
	c.v.s.; h.s.	s.s.	s.s.	190		6
	h.s.s.	s.	s.f., s. alk.	subl.		7
	s.s. $CHCl_3$	v.s.s.	v.s.s.	275—280		8
	1 : 4030/15°	v.s.s.	i.	d.		9
	h.s.s.	s.		160		10
	0.0058 : 100/25°	s.	s.	182	>300	11
	s.s.	s.			291.6	12
	h.s.s.	v.s.	v.s.	60		13
1.224/4°	h.s.s.	s.	s.	96	278—280	14
1.217/4°	h.s.s.	s.	s.	122	285—286	15
	v.s.			d. 170		16
	s.			110—120		17
	v.s.			107, an. 100		18
	del.			101		19
		v.s.		33.5	296.5	20
		v.s.	v.s.	66.5	304—305	21
1.425	s. $C_6\bar{H}_6$	s.s.	s.s.	142	>360	22
				233		23
	h.s.s.			liq.	>300	24
	s.s.	s.	s.	82	>300	25
	v.s.s.	v.s.	v.s.	52	352	26
	h.s.	v.s.	v.s.	93.5	349.5—350 /741mm.	27
	s., s. $CHCl_3$	s.	s. C_6H_6	125		28
	s., s. $CHCl_3$	s.	s. C_6H_6	d. 115—120		29
	s.s.	s.s.	s. C_6H_6, $CHCl_3$	154	>360	30
1.1011/50°	0.167 : 100, c	v.s.	v.s.	51	300	31
1.0614/98°	s.			112	306.1	32
	h.s.	v.b.	s.	95		33
	h.s.	s. $CHCl$	s.	186	subl.	34
	s.	m.	m	64	subl.	35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Naphthyl hydrazine, α	$C_{10}H_7NH.NH_2$	158.15	$C_{10}H_{10}N_2$
2	——, β	,, ,,	158.15	
3	— mercaptan, thionaphthol α	$C_{10}H_7SH$	160.17	$C_{10}H_8S$
4	——,—, β	,, ,,	160.17	,,
5	— phenyl ketone, α	$C_{10}H_7.CO.C_6H_5$	232.18	$C_{17}H_{12}O$
6	———, β	,, ,,	232.18	,,
7	—— methane, α	$C_{10}H_7.CH_2.C_6H_5$	218.20	$C_{17}H_{14}$
8	———, β	,, ,,	218.20	
9	Neurine	$C_2H_3N(CH_3)_3OH$	103.14	$C_5H_{13}ON$
10	Nicotinic acid	$C_5H_4N.COOH$	123.08	$C_6H_5O_2N$
11	Nitracetanilide, o	$NO_2.C_6H_4.NH.COCH_3$	180.12	$C_8H_8O_3N_2$
12	—, m	,, ,,	180.12	,,
13	—, p	,, ,,	180.12	,,
14	Nitranilic acid	$C_6(NO_2)_2.O_2.(OH)_2$	230.07	$C_6H_2O_6N_2$
15	Nitraniline, o	$NO_2.C_6H_4.NH_2$	138.10	$C_6H_6O_2N_2$
16	—, m	,, ,,	138.10	
17	—, p	,, ,,	138.10	,,
18	Nitro alizarin, 4:1:2	$C_{14}H_5O_2(NO_2)(OH)_2$	285.14	$C_{14}H_7O_6$ľ
19	——, 3:1:2	,, ,,	285.14	,,
20	— anisol, o	$NO_2.C_6H_4.OCH_3$	153.10	$C_7H_7O_3N$
21	——, m	,, ,,	153.10	,,
22	——, p	,, ,,	153.10	,,
23	— anthraquinone, 1	$C_{14}H_7O_2.NO_2$	253.14	$C_{14}H_7O_4N$
24	——, 2	,, ,,	253.14	
25	— benzamide, o	$C_6H_4(NO_2)CONH_2$	166.10	$C_7H_6O_3N_2$
26	——, m	,, ,,	166.10	,,
27	——, p	,, ,,	166.10	,,
28	— benzaldehyde, a	$C_6H_4(NO_2)CHO$	151.09	$C_7H_5O_3N$
29	——, m	,, ,,	151.09	,,
30	——, p	,, ,,	151.09	,,
31	— benzene	$C_6H_5NO_2$	123.08	$C_6H_5O_2N$
32	— benzoic acid, o	$C_6H_4(NO_2)COOH$	167.09	$C_7H_5O_4N$
33	———, m	,, ,,	167.09	,,

Density H$_2$O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	c.v.s.s.	h.v.s.s.	v.s.s.	116—117	203/20mm.	1
		h.s.s.		124—125		2
	i.		liq.		285 d.	3
				79—81	286	4
		(abs.) 1:41/12°		75.5	385	5
		(abs.) 1:49/12°		82	398/745mm.	6
	s.C$_6$H$_6$, CS$_2$	1:30, h.	s.	59	350	7
				35.5	350	8
	v.s.	s.	s.s.	liq.		9
	h.s.	s.	i.	228—229		10
	h.v.s		v.s. KOH	92—93		11
	h.s.		i. KOH	150—152		12
			s. KOH	210—211		13
	v.s.	v.s.	i.	100	d. 170	14
1.442	h.s.	s.	v.s.	71.5		15
1.430	1:600/18.5°	11.26:100	7.05:100	114	285	16
1.437/14°	1:1250/18.5°	5.84:100	6.1:100	148.3		17
	s.s.	s.	s. KOH	289 d.		18
	s.s.	v.s.	s. C$_6$H$_6$, CHCl$_3$	244 d.		19
1.286/20°				9	265	20
				38	258	21
1.233/20°				54	258—260	22
		s.s.	s.s.	220	subl.	23
	i.	v.s.s.	v.s.s.	184—185	subl.	24
	h.s.	s.		174	317	25
	s.	s.		140—142	310—315	26
	s.s.	s.		197—198		27
	s.s.	s.	s.	46	153/23mm.	28
	h.s.	s.	s.	58	164/23mm.	29
	h.s.	s.	s.s.	106		30
1.1866/14°	i.	s.	s.	5.7	210.9	31
1.575/4°	0.611:100/16.5°	1:3/10°	2.16:7/11°	147--148		32
1.494/4°	0.235:100/16.5°	5:9/10°	2.51:7/11°	140.4		33

Name.	Formula.	Formula. Weight.	Empirical Formula.
1 **Nitro benzoic acid**, *p*	$C_6H_4(NO_2)COOH$	167.09	$C_7H_5O_4N$
2 — benzoate, ethyl, *o*	$C_6H_4(NO_2)COOC_2H_5$	195.12	$C_9H_9O_4N$
3 ——, —, *m*	,, ,,	195.12	,,
4 ——, —, *p*	,, ,,	195.12	,,
5 ——, methyl *o*	$C_6H_4(NO_2)COOCH_3$	181.10	$C_8H_7O_4N$
6 ——, —, *m*	,, ,,	181.10	,,
7 ——, —, *p*	,, ,,	181.10	,,
8 — benzonitrile, *o*	$C_6H_4(NO_2)CN$	148.08	$C_7H_4O_2N_2$
9 ——, *m*	,, ,,	148.08	,,
10 ——, *p*	,, ,,	148.08	,,
11 — benzoyl formate, *o*	$C_6H_4(NO_2)CO.COOH$	195.09	$C_8H_5O_5N$
12 — benzyl alcohol, *o*	$C_6H_4(NO_2).CH_2OH$	153.10	$C_7H_7O_3N$
13 ———, *m*	,, ,,	153.10	,,
14 ———, *p*	,, ,,	153.10	,,
15 —— chloride, *o*	$C_6H_4(NO_2)CH_2Cl$	171.55	$C_7H_6O_2NCl$
16 ———, *m*	,, ,,	171.55	,,
17 ———, *p*	,, ,,	171.55	,,
18 — benzylidine chloride, *m*	$C_6H_4(NO_2)CHCl_2$	206.01	$C_7H_5O_2NCl_2$
19 ———, *p*	,, ..	206.01	,,
20 — bromoform	$C(NO_2)Br_3$	297.78	CO_2NBr_3
21 — camphor, α	$C_{10}H_{15}O.NO_2$	197.18	$C_{10}H_{15}O_3N$
22 — cinnamic acid, *o*	$C_6H_4(NO_2)CH:CH.COOH$	193.11	$C_9H_7O_4N$
23 ———, *m*	,, ,,	193.11	,,
24 ———, *p*	,, ,,	193.11	,,
25 — cinnamate, ethyl	$C_6H_4(NO_2)CH:CH.COOC_2H_5$	221.15	$C_{11}H_{11}O_4N$
26 — cresol	$CH_3.C_6H_3(NO_2)OH$	153.10	$C_7H_7O_3N$
27 $CH_3:OH:NO_2=1:2:3$			
28 ——, 1:2:5	,, ,,	153.10	,,
29 ——, 1:3:4	,, ,,	153.10	,,
30 ——, 1:3:6	,, ,,	153.10	,,
31 ——, 1:4:3	,, ,,	153.10	,,
32 — cumene	$C_6H_4(NO_2)CH:(CH_3)_2$	165.14	$C_9H_{11}O_2N$
dimethyl aniline, *o*	$C_6H_4(NO_2)N:(CH_3)_2$	166.14	$C_8H_{10}O_2N_2$
33 ———, *m*	,, ,,	166.14	,,
34 ———, *p*	,, ,,	166.14	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.610/20°	0.04 : 100/20°	0.18 : 9/10°	0.22 : 7/11°	237		1
				29—30	173/18mm.	2
				47	296	3
				57		4
1.2855/20°					149—151/12mm.	5
		v.s.CH₃OH		70	279	6
				96		7
	h.s., s. CH₂	s., s. CHCl₃	s. C₆H₆	109		8
	s.s.	s.	s.	115		9
	s.s.	h.s.	s. CHCl₃	147.5—148.5		10
	warm, m.			an. 123		11
	s.s.	s.	s.	74	168/20mm.	12
		s.	s.	27	175—180/3	13
	h.s.	s.	s.	93	185/12mm.	14
		s.		48—49		15
		s.		45—47	173—178/ 30—35mm.	16
		s.		71		17
		h.s.	s.	65		18
						19
		s.	s.	46		19
2.5				10.2	127/48mm.	20
	s. CHCl₃	s.	s. C₆H₆	10.3		21
	i.	h.s.		240		22
				196—197		23
	n.s.s.	h.s.s.	s.s.	285—286		24
	v.s. C₆H₆	v.s.	v.s., v.s. CS₂	42		25
	i.	v.s.s.	v.s.s.	54		26
						27
	v.s.	v.s.s.	v.s.s.	94.6—95		28
	s.s.	s.s.	s.s.	56		29
	c.v.s.	v.s.s.	v.s.s.	129		30
		v.s.s.	v.s.s.	127—129		31
				liq.		32
					151—153/ 30—33mm.	33
	i.	s.	s.	60—61	280—285 d.	33
	i.	s.		162—163		34

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Nitro diphenyl, o	$C_6H_5.C_6H_4.NO_2$	199.14	$C_{12}H_9O_2N$
2 — —, m	,, ,,	199.14	,,
3 — —, p	,, ,,	199.14	,,
4 — ethane	$C_2H_5.NO_2$	75.06	$C_2H_5O_2N$
5 — erythrol	$C_4H_6(ONO_2)_4$	302.11	$C_4H_6O_{12}N_4$
6 — glycerin, tri-	$C_3H_5(ONO_2)_3$	227.09	$C_3H_5O_9N_3$
7 — —, di- $\alpha\gamma$	$C_3H_5(OH)(ONO_2)_2$	183.09	$C_3H_6O_7N_2$
8 — —, di-, $\alpha\beta$	,, ,,	183.09	,,
9 — —, mono-, α	$C_3H_5(OH)_2(ONO_2)$	137.08	$C_3H_7O_5N$
10 — —, mono, β	,, ,,	137.08	,,
11 — guanidine	$CH_4N_3.NO_2$	104.07	$CH_4O_2N_4$
12 — isatin	$C_8H_4NO_2.NO_2$	192.09	$C_8H_4O_4N_2$
13 — isoquinoline	$C_9H_5(NO_2):C_3H_3N.H_2O$	210.11	$C_9H_8O_3N_2$
14 — mannitol	$C_6H_8(ONO_2)_6$	452.15	$C_6H_8O_{18}N_6$
15 — mesitylene, $(CH_3)_3:NO_2=1:3:5:2$	$C_6H_2(CH_3)_3NO_2$	165.14	$C_9H_{11}O_2N$
16 — methane	$CH_3.NO_2$	61.04	CH_3O_2N
17 — naphthalene, α	$C_{10}H_7.NO_2$	173.12	$C_{10}H_7O_2N$
18 — —, β	,,	173.12	,,
19 — naphthol, 1:2	$C_{10}H_6OH.NO_2$	189.12	$C_{10}H_7O_3N$
20 — —, 1:4	,, ,,	189.12	,,
21 — —, 1:5	,, ,,	189.12	,,
22 — —, 2:1	,, ,,	189.12	,,
23 — —, 2:5	,, ,,	189.12	,,
24 — —, 2:6	,, ,,	189.12	,,
25 — naphthylamine, 1:2	$C_{10}H_6NH_2.NO_2$	188.13	$C_{10}H_8O_2N_2$
26 — —, 1:4	,, ,,	188.13	,,
27 — —, 2:1	,, ,,	188.13	,,
28 — —, 1:8	,, ,,	188.13	,,
29 — —, 1:5	,, ,,	188.13	,,
30 — —, 2:5	,, ,,	188.13	,,
31 — —, 2:8	,, ,,	188.13	,,
32 — phenetol, o	$C_2H_5O.C_6H_4.NO_2$	167.12	$C_8H_9O_3N$
33 — —, m	,, ,,	167.12	,,
34 — —, p	,, ,,	167.12	,,
35 — phenol, o	$C_6H_4OH.NO_2$	139.08	$C_6H_5O_3N$
36 — —, m	,, ,,	139.08	,,
37 — —, p	,, ,,	139.08	,,

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
				37	320	1
				61		2
	s. CHCl₃	h.s.	s.	114—114.5	340	3
1.0582/13°	i.			114—114.8		4
	h.s.	s.		61	expl.	5
1.6009/15°	0.16 : 100	1 : 3.5	m.	13.3	expl. 260	6
1.47	7.7 : 100			liq. ⎫	146—148	7
				liq. ⎬	/15 mm.	8
1.40	70 : 10	v.s.	v.s.	58 ⎫	155—160	9
				54 ⎬	/15mm.	10
	c.v.s.s.	v.s.s.	i.	230 d.		11
	s.s.	s.	s. KOH	226—230		12
	h.s.	s.		110		13
1.604/0°	h.s.	1 : 34.4 /12.8°	1 : 24.4 /9°	108		14
	s. C₆H₆	s.	s.	41—42	255	15
1.1441/15°	s.s.		s. alk.	- 26.5	101/762mm.	16
1.331/4°				61	304	17
	s. CHCl₃	s.		79	160—170 /15mm.	18
	v.s.s.	s.s. (dil.)		128		19
	h.s.	v.s.	s. acetic.	164		20
				171		21
				165		22
				103		23
				144—145		24
		s.		144		25
		s.	s. acetic.	191		26
	h.s.	s.		123—124		27
				96—97		28
	s.			118—119		29
				143.5		30
				103.5		31
				2.1	267—268/757mm	32
				34	264	33
1.180/15°				57.8	283/758mm.	34
1.2945/45.2°	n.s.	s.	s.	44.3	214	35
1.492	h.s.	v.s.	v.s.	96	194/70mm.	36
1.2809/14°	s.s.	v.s.		114		37

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Nitro phenyl acetic acid, o	$NO_2.C_6H_4.CH_2.COOH$	181.10	$C_8H_7O_4N$
2	——, m	,, ,,	181.10	,,
3	——, p	,, ,,	181.10	,,
4	—— hydrazine, o	$NO_2.C_6H_4.NH.NH_2$	153.11	$C_6H_7O_2N_3$
5	——, m	,, ,,	153.11	,,
6	——, p	,, ,,	153.11	,,
7	—— propiolic acid, o	$C_6H_4(NO_2)C : C.COOH$	191.10	$C_9H_5O_4N$
8	——, p	,,	191.10	,,
	— phthalic acid, COOH : COOH : $NO_2=$			
9	1:2:3	$C_6H_3(NO_2)(COOH)_2$	211.11	$C_8H_5O_6N$
10	1:2:4	,, ,,	211.11	,,
11	1:3:5	,, ,,	211.11	,,
12	1:3:2	,, ,,	211.11	,,
13	1:3:4	,, ,,	211.11	,,
14	1:4:2	,, ,,	211.11	,,
	— pseudo cumene, $(CH_3)_3 : NO_2=1:2:4:3$			
15		$C_6H_3(NO_2)(CH_3)_3$	165.14	$C_9H_{11}O_2N$
16	1:2:4:5	,, ,,	165.14	,,
17	1:2:4:6	,, ,,	165.14	,,
18	— quinoline, 8	$C_9H_6N.NO_2$	174.11	$C_9H_6O_2N_2$
19	——, 7	,,	174.11	,,
20	——, 6		174.11	,,
21	——, 5	$C_9H_6N.NO_3$	174.11	$C_9H_6O_2N_2$
	— salicylic acid, COOH : OH : $NO_2=$			
22	1:2:6	$C_6H_3(NO_2)(OH)COOH$	183.09	$C_7H_5O_5N$
23	1:2:5	,, ,,	183.09	,,
24	1:2:3	,, ,, $(.H_2O)$	183.09	,,
25	1:2:4	,, ,,	183.09	,,
26	2:3:2	,, ,, $(.H_2O)$	183.09	,,
27	1:3:4	,, ,,	183.09	,,
28	1:3:5	,, ,, $(.H_2O)$	183.09	,,
29	1:3:6	,, ,,	183.09	,,
30	1:4:3	,, ,,	183.09	,,

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	v.s.			141		1
	s.			117		2
	c.v.s.	s.s.		114		3
	h.s.s.; c.s.	s.s.	s.s.	90		4
	h.v.s.	v.s.		93		5
		h.s.		157 d.		6
	h.s.	s.	s., s.s. CHCl₃	155—156 d.		7
	s.s.	h.s.	s.	181	d.	8
	h.s.	v.s.	s.	218		9
	v.s.	v.s.	v.s.	161		10
	s.s.	v.s.		248—249		11
				315		12
				246		13
				270		14
		s.		30		15
		s.		20	265	16
				71		17
	h s.	s.	s., s. C₆H₆	88—89		18
		c.v.s.s	s.	132—133		19
	h.s.	h.s.	s.s., s. C₆H₆	149—150	subl.	20
	h.s.s.			72	subl.	21
	s. acetone	s.s.	v.s.s.	130		22
1.650	1:1475 /15.5°	v.s.		228		23
	1:770 /15.5°	s.	s., s. C₆H₆	125, an. 144		24
				235		25
				178		26
				230		27
				167		28
				169		29
				185		30

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Nitro resorcin, $(OH)_2:NO_2=1:3:2$	$(OH)_2:C_6H_3.NO_2$	155.08	$C_6H_5O_4N$
2	Nitroso benzene	$C_6H_5.NO$	107.08	C_6H_5ON
3	— diethylamine	$(C_2H_5)_2:N.NO$	102.12	$C_4H_{10}ON_2$
4	— dimethyl aniline, p	$(CH_3)_2:N.C_6H_4.NO$	150.14	$C_8H_{10}ON_2$
5	— diphenylamine, N	$(C_6H_5)_2:N.NO$	198.16	$C_{12}H_{10}ON_2$
6	— naphthol, 1:2	$C_{10}H_6OH.NO$	173.11	$C_{10}H_7O_2N$
7	——, 1:4	,, ,,	173.11	,,
8	——, 2:1	,, ,,	173.11	,,
9	— phenol, p	$OH.C_6H_4.NO$	123.09	$C_6H_5O_2N$
10	Nitro styrolene, o	$NO_2.C_6H_4.CH:CH_2$	149.10	$C_8H_7O_2N$
11	——, m	,, ,,	149.10	,,
12	——, p	,, ,,	149.10	,,
13	— thiophen	$C_4H_3S.NO_2$	129.11	$C_4H_3O_2NS$
14	— toluene, o	$C_6H_4(NO_2)CH_3$	137.10	$C_7H_7O_2N$
15	——, m	,, ,,	137.10	,,
16	——, p	,, ,,	137.10	,,
	— toluidine, $CH_3:NH_2:NO_2=$			
17	1:2:3	$C_6H_3(CH_3)(NH_2)NO_2$	152.12	$C_7H_8O_2N_2$
18	1:2:4	,, ,,	152.12	,,
19	1:2:5	,, ,,	152.12	,,
20	1:3:4	,, ,,	152.12	,,
21	1:2:6	,, ,,	152.12	,,
22	1:3:2	,, ,,	152.12	,,
23	1:3:5	,, ,,	152.12	,,
24	1:3:6	,, ,,	152.12	,,
25	1:4:2	,, ,,	152.12	,,
26	1:4:3	,, ,,	152.12	,,
27	— urea	$NH_2.CO.NH.NO_2$	105.06	$CH_3O_3N_3$
28	— urethane	$C_2H_5.O.CO.NH.NO_2$	134.08	$C_3H_6O_4N_2$
	— xylene, $CH_3:CH_3:NO_2=$			
29	1:2:3	$C_6H_3(CH_3)NO_2$	151.12	$C_8H_9O_2N$
30	1:2:4	,, ,,	151.12	,,
31	1:3:2	,, ,,	151.12	,,
32	1:3:4	,, ,,	151.12	,,
33	1:3:5	,, ,,	151.12	,,
34	1:4:2	,, ,,	151.12	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
			s.	85		1
	s.	s.		68		2
0.951/17.5°					176.9	3
	i.	s.	s.	85		4
		h.s.	h.v.s.C₆H₆	66.5		5
		s.	s. acetone	162—164		6
	h.v.s.s.	l :42/13°	s.	190		7
				112		8
	s.	s.	s.	140 d.		9
	s. H₂SO₄			12—12.5	d.	10
	s. CHCl₃	s. (abs.)	s.	16	230—231	11
		s.	v.s.	58	250—260	12
				44	224—225	13
1.1629/20°	i. alk.	s.		− 3.85	222.3	14
1.168/22°	i.	s.		16.1	230—231 /756mm	15
1.1232/54°		s.		51.6—51.9	237.7	16
	s. CHCl₃	s.	s., s. C₆H₆	91.5		17
1.365	s. acetone	s.	s.	104—105		18
1.366	h.s.s.	s.		127—128		19
				109		20
1.378	h.s.s.	v.s.	s., v.s. C₆H₆	91.5		21
	s.s.s.	s.		53		22
	v.s.s.	s., s. C₆H₆	v.s.	98—98.4		23
			s. ac.	138		24
	s.	s.s.s. CS₂		77.5		25
1.312	h.v.s.s.	s.		116		26
	s.	s.				27
	s.	s.	s.	64	140 d	28
1.147/15°				7—9	250/739mm	29
1.139/30°		m. >30°		29	258	30
1.112/15°				13	225/744mm.	31
1.126/17.5					237—239	32
		s.	s.	74—75	273/739mm.	33
1.132/15°			liq.		238.5—239 /739mm.	34

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Nonadecane	$C_{19}H_{40}$	268.42	$C_{19}H_{40}$
2 Nonane, norm.	$CH_3.(CH_2)_7.CH_3$	128.21	C_9H_{20}
3 —, isobutyl isoamyl	$(CH_3)_2:CH.(CH_2)_2.CH:$	128.21	,,
4 Nonyl alcohol, norm.	$C_9H_{19}OH \quad (CH_3)_2$	144.21	$C_9H_{20}O$
5 — —, ethyl hexyl carbinol	$C_2H_5.CHOH.C_6H_{13}$	144.21	,,
6 Nonylene	C_9H_{18}	126.15	C_9H_{18}
7 Nonylic acid	$C_8H_{17}COOH$	158.15	$C_9H_{18}O_2$
8 Nucin, see	Hydroxy naphthoquinone		,,
9 Octa decane	$C_{18}H_{38}$	254.39	$C_{18}H_{38}$
10 — decyl alcohol	$C_{18}H_{38}O$	270.39	$C_{18}H_{38}O$
11 — decylene, norm.	$CH_3.(CH_2)_{15}CH:CH_2$	252.38	$C_{18}H_{36}$
12 — —, sec.	$C_{18}H_{36}$	252.38	,,
13 Octane, norm.	C_8H_{18}	114.18	C_8H_{18}
14 —, di-isobutyl	$(CH_3)_2:CH.(CH_2)_3.CH:$	114.18	,,
15 Octyl alcohol, norm.	$C_8H_{18}O \quad (CH_3)_2$	130.18	$C_8H_{18}O$
16 — —, methyl hexyl carbinol	$CH_3.(CH_2)_5.CHOH.CH_3$	130.18	,,
17 — —, diethyl propyl carbinol	$(C_2H_5)_2.COH.C_3H_7$	130.18	,,
18 — amine, norm.	$C_8H_{17}.NH_2$	129.20	$C_8H_{19}N$
19 — —, sec.	$CH_3.CH(NH_2)C_6H_{13}$	129.20	,,
20 — chloride, norm.	$C_8H_{17}Cl$	148.64	$C_8H_{17}Cl$
21 — —, sec.	,,	148.64	,,
22 Octylene, norm.	C_8H_{16}	112.17	C_8H_{16}
23 —, di-isopropyl ethylene	$(CH_3)_2:CH.CH:CH.CH: \quad (CH_3)_2$	112.17	,,
24 —, di-iso butylene	$(CH_3)_2C:CH.CH:C(CH_3)_2$	112.17	,,
25 Œnanthic acid, see	Heptylic acid		
26 Œnanthine, see	Heptine		
27 Œnanthol, see	Heptyl alcohol		
28 Oleic acid	$C_{17}H_{33}COOH$	282.36	$C_{18}H_{34}O_2$
29 Olein	$C_3H_5(C_{18}H_{33}O_2)_3$	885.12	$C_{57}H_{104}O_6$
30 Opianic acid	$C_6H_2(OCH_3)_2(CHO)COOH$	210.13	$C_{10}H_{10}O_5$
31 Opianin, see	Narcotine		
32 Orceïne	$C_{28}H_{24}N_2O_7$	500.35	$C_{28}H_{24}O_7N_2$
33 Orcinol, see	Dihydroxy toluene		
34 — phthalein	$C_{22}H_{16}O_5$	360.24	$C_{22}H_{16}O_5$
35 Orsellic acid, 2:6:4:1	$C_6H_2(OH)_2(CH_3)COOH$	168.10	$C_8H_8O_4$

Density $H_2O=1$.	Solubility in			M.P. °C.	B.P. °C.	
	Water.	Alcohol.	Ether.			
0.777/32°				32	330	1
0.7177/20°				liq.	150	2
0.7247/0°					132—133	3
0.855/18.5°				– 5	213.5	4
0.825/20°				liq.	195/750mm.	5
0.7433/20°					147—148	6
	s.	s.	s.	12—12.5	254	7
						8
0.7668/28°				30	305—307	9
0.8124/59°		s.		59	210.5/15	10
0.791/18°				18	179/15mm.	11
0.942/15°	i.	v.s.s.	s, s. CS_2	63—64	440	12
0.7188/0°				liq.	125.8	13
0.7001/12°				liq.	108.5	14
0.8375/0°				– 15	195.5	15
0.823/16°					179.5	16
0.8379/20°					160.5	17
					185—187	18
0.786					162.5	19
0.8802/16°					179.5—180.5	20
0.8708/15°					175	21
0.7217/17°					122—123	22
				liq.	116—120	23
0.734/0°					102.5/756	24
						25
						26
						27
0.898/14°	i.	s.	s.	14	286/100	28
	i.	v.s.s.	v.s.	– 5		29
	1 : 400, c.	s.	s.	150		30
	1 : 60, h.					31
	s. $CHCl_3$	s.	s.			32
						33
	i.	s.	i., s. alk.	d. 230		34
	s.	v.s.	1 : 4.5/20°	d. 176		35

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Ortho acetate, ethyl	$CH_3.C(OC_2H_5)_3$	162.18	$C_8H_{18}O_3$
2 — formate, ethyl	$CH(OC_2H_5)_3$	148.16	$C_7H_{16}O_3$
3 Osotriazole	$HC=N{>}NH$ / $HC=N$	69.06	$C_2H_3N_3$
4 Oxalacetic ester	$C_2H_5.OOC.CO.CH_2.$ $COO.C_2H_5$	188.14	$C_8H_{12}O_5$
5 Oxalic acid	$COOH.COOH.2H_2O$	126.06	$C_2H_2O_4$
6 Oxalate, ammonium	$(COONH_4)_2(.H_2O)$	124.09	$C_2H_8O_4N_2$
7 —, calcium	$(COO)_2Ca(.H_2O)$	134.08	C_2O_4Ca
8 —, potassium	$(COOK)_2(.H_2O)$	166.21	$C_2O_4K_2$
9 —, — hydrogen	$(COO)_2HK$	128.12	C_2HO_4K
10 —, — —	$(COO)_2HK(COOH)_2.2H_2O$	254.17	$C_4H_5O_8K$
11 —, allyl	$(COO.C_3H_5)_2$	170.12	$C_8H_{10}O_4$
12 —, ethyl	$(COO.C_2H_5)_2$	146.11	$C_6H_{10}O_4$
13 —, methyl	$(COO.CH_3)_2$	118.07	$C_4H_6O_4$
14 Oxaluramide	$C_3H_5N_3O_3$	131.09	$C_3H_5O_3N_3$
15 Oxaluric acid	$NH_2.CO.NH.CO.COOH$	132.07	$C_3H_4O_4N_2$
16 Oxalyl chloride	$(COCl)_2$	126.93	$C_2O_2Cl_2$
17 Oxamethane	$C_2O_2NH_2(OC_2H_5)$	117.09	$C_4H_7O_3N$
18 Oxamide	$C_2O_2(NH_2)_2$	88.06	$C_2H_4O_2N_2$
19 Oxaminic acid	$C_2O_2(NH_2)OH$	89.04	$C_2H_3O_3N$
20 Oxanilide	$C_2O_2(NH.C_6H_5)_2$	240.19	$C_{14}H_{12}O_2N_2$
21 Oxanthrol	$C_6H_4:(CO)CH(OH):C_6H_4$	210.15	$C_{14}H_{10}O_2$
22 Oximide	$CO{>}NH$ / CO	61.03	C_2HO_2N
23 Oxindole	$C_6H_4 {<} CH_2 / CO / NH$	133.11	C_8H_7ON
24 Palmitic acid	$C_{15}H_{31}COOH$	256.34	$C_{16}H_{32}O_2$
25 Palmitin	$C_3H_5(C_{16}H_{31}O_2)_3$	807.04	$C_{51}H_{98}O_6$
26 Palmitone	$(C_{15}H_{31})_2:CO$	450.65	$C_{31}H_{62}O$
27 Palmitonitrile	$C_{15}H_{31}CN$	237.34	$C_{16}H_{31}N$
28 Parabanic acid	$C_3H_2N_2O_3.H_2O$	132.07	$C_3H_4O_4N_2$
29 Paraconic acid	$CH_2:CH.COOH$ / $O.CO.CH_2$	130.07	$C_5H_6O_4$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
					142	1
0.8971/18.8°	v.s.s.		liq.	146		2
	m.			22.5	203—204 /714mm.	3
1.159/23.5°	i.	m.	m.	liq.	131—132 /24mm.	4
1.653/18.5°	1 : 10.46 /14.5°	1 : 2.5, c.	1.266 : 100/15°	98 an. 189.5		5
1.475	1 :23.7/15°					6
2.200	i.		s. ac.			7
2.080	1 : 3.03/16°					8
	s.s.					9
	1 : 26.21/8°					10
1.05/15°	i.	s.		liq.	206—207	11
1.0793/20°	s.s.	s.		– 40.6	184/740	12
1.1566	s.s.	s.		54	163.3	13
	c.i.	c.s. KOH	s. H_2SO_4	> 310		14
	c.v.s.s.					15
				– 12	64	16
0.808/19°				i114—115		17
1.667	h.s.s.	s. NH_4OH		417—419		18
	1 : 58/17°, h.d.	i. (abs.)		d. 210		19
	h.i.	h.s.s.	i.	245	320	20
	s. alk.			204—206 d		21
	c.v.s.s.	warm, s. dil. NH_4OH				22
	h.s.	s.		126		23
0.8527/64°	i.	s.s.	v.s.	62.6	278/100	24
				61.5		25
0.7997/82.8°						26
0.8224/31°				31	251.5/100	27
	1 :21/8°		i.	242—244 d.		28
	s.			57—58		29

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Para cyanogen	$(CN)_6$	156.12	C_6N_6
2	— formaldehyde	$(CH_2O)_2$	60.04	$C_2H_4O_2$
3	Paraldol	$(C_4H_8O_2)_2$	176.17	$C_8H_{16}O_4$
4	Paraldehyde	$C_6H_{12}O_3$	132.13	$C_6H_{12}O_3$
5	Para leucaniline	$CH(C_6H_4.NH_2)_3$	289.28	$C_{19}H_{19}N_3$
6	Param, dicyanogen diamide	$C_2N_2(NH_2)_2$	84.10	$C_2H_4N_4$
7	Para rosaniline	$C(OH)(C_6H_4.NH_2)_3$	305.28	$C_{19}H_{19}ON_3$
8	Parvolin, α	$C_9H_{13}N$	135.16	$C_9H_{13}N$
9	—, β	$C_5HN(CH_3)_4$	135.16	,,
10	—, 2-methyl-5-propyl pyridine	$C_5H_3N(CH_3)(C_3H_7)$	135.16	,,
11	—, 2 : 4-diethyl pyridine	$C_5H_3N(C_2H_5)_2$	135.16	,,
12	—, 3 : 5-dimethyl-2-ethyl pyridine	$C_5H_2N(CH_3)_2(C_2H_5)$	135.16	,,
13	—, 2 : 5-dimethyl-4-ethyl pyridine	,, ,,	135.16	,,
14	Pelargonic acid, see	Nonylic acid		
15	Pelargonate, ethyl	$C_8H_{17}O_2.C_2H_5$	186.23	$C_{11}H_{22}O_2$
16	Penta acetyl glucose, α	$C_6H_7O(C_2H_3O_2)_5$	390.26	$C_{16}H_{22}O_{11}$
17	———, β	,,	390.26	,,
18	— amino benzene	$C_6H(NH_2)_5$	153.17	$C_6H_{11}N_5$
19	— bromo benzene	C_6HBr_5	472.64	C_6HBr_5
20	— chlor aniline	$C_6Cl_5.NH_2$	265.36	$C_6H_2NCl_5$
21	— — benzene	C_6HCl_5	250.34	C_6HCl_5
22	— ethane	C_2HCl_5	202.32	C_2HCl_5
23	— erythrite	$C(CH_2OH)_4$	136.12	$C_5H_{12}O_4$
24	— glycol	$(CH_3)_2C : (CH.OH)_2$	104.12	$C_5H_{12}O_2$
25	— methyl amino benzene	$C_6(CH_3)_5NH_2$	163.20	$C_{11}H_{17}N$
26	— — benzene	$C_6H(CH_3)_5$	148.18	$C_{11}H_{16}$
27	— — ethanol	$(CH_3)_3C.C(OH)(CH_3)_2$	116.16	$C_7H_{16}O$
28	— — — hydrate	$2C_7H_{16}O.H_2O$	250.35	$C_{14}H_{34}O_3$
29	— methylene, see	Cyclo pentane		
30	— — bromide	$CH_2Br.(CH_2)_3.CH_2Br$	229.95	$C_5H_{10}Br_2$
31	— — diamine, (cadaverine)	$NH_2.CH_2.(CH_2)_3.CH_2.NH_2$	102.16	$C_5H_{14}N_2$
32	— — dicarboxylic acid, 1 : 3	$C_5H_8(COOH)_2$	158.12	$C_7H_{10}O_4$

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.	i.	s. KOH		subl.	1
	s.			152		2
				80—90	90—100	3
0.998/15°	1 : 8			12.6	124	4
		s.		148		5
	s.	s.	s.s.	204		6
	i.	s.				7
0.986/22°				liq.	188	8
				liq.	220	9
1.066/0°	v.s.	s.	s.	liq.	>200	10
0.9338/0°	s.s.			liq.	187—188	11
0.9418/0°				liq.	198—200	12
0.916/14°	1 : 76/0°			liq.	186	13
						14
0.8655/17.5°		s.		liq.		15
				111-112		16
				127—128		17
	v.s.	i.	i.			18
		s.		158		19
		s.	s.	232		20
1.8342/16.5°				85—86	275—277	21
1.709/0°				<—18	160.5	22
				253		23
	s.			129	206/747mm	24
	i.	s.	s.	151—152	277—278	25
				53	230	26
				17	131	27
	s.s.			83		28
						29
				- 34.5	204—206	30
0.8846/15°	s.	s.	s.s.		178—179	31
				121	214	32

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Penta methyl phenol	$C_6OH(CH_3)_5$	164.18	$C_{11}H_{16}O$
2 — — rosaniline	$C_{24}H_{29}N_3O$	375.38	$C_{24}H_{29}O_3N$
3 Pentadiene, see Piperylene			
4 Pentane, norm.	$CH_3.(CH_2)_3.CH_3$	72.12	C_5H_{12}
5 —, sec.	$(CH_3)_2:CH.CH_2.CH_3$	72.12	,,
6 —, tert.	$C(CH_3)_4$	72.12	,,
7 Pentahydroxy pentane	$C_5H_7(OH)_5$	152.12	$C_5H_{12}O_5$
8 Per chlor ether	$C_4Cl_{10}O$	418.62	C_4OCl_{10}
9 — — ethylene	$CCl_2:CCl_2$	165.85	C_2Cl_4
10 — — methyl mercaptan	$CCl_3.SCl$	185.90	CCl_4S
11 — thiocyanic acid	$C_2N_2H_2S_3$	150.23	$C_2H_2N_2S_3$
12 Phellandrene	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
13 Phenacetin	$C_6H_4(OC_2H_5)NH.CO.CH_3$	179.16	$C_{10}H_{13}O_2N$
14 Phenanthra hydroquinone, 9 : 10	$C_{14}H_8(OH)_2$	210.15	$C_{14}H_{10}O_2$
15 Phenanthra quinone	$C_{14}H_8O_2$ (9 : 10)	208.13	$C_{14}H_8O_2$
16 Phenanthrene	$C_6H_4.CH$ $\|\|$ $\|\|$ $C_6H_4.CH$	178.15	$C_{14}H_{10}$
17 Phenanthron, 9	$C_{14}H_9(OH)$	194.15	$C_{14}H_{10}O$
18 Phenazine	$C_6H_4:N.N:C_6H_4$	180.14	$C_{12}H_8N_2$
19 Phenethylamine, β	$C_6H_5.CH_2.CH_2.NH_2$	121.14	$C_8H_{11}N$
20 —, a	$C_6H_5.CH(NH_2).CH_3$	121.14	,,
21 Phenetidine, o	$C_2H_5.O.C_6H_4.NH_2$	137.14	$C_8H_{11}ON$
22 —, m	,, ,,	137.14	,,
23 —, p	,, ,,	137.14	,,
24 Phenetol	$C_2H_5.O.C_6H_5$	122.12	$C_8H_{10}O$
25 Phenol	C_6H_5OH	94.08	C_6H_6O
26 — phthalein	$(C_6H_4OH)_2:C(COO):C_6H_4$	318.21	$C_{20}H_{14}O_4$
27 — phthaline	$(C_6H_4OH)_2:CH.C_6H_4.COOH$	320.23	$C_{20}H_{16}O_4$
28 — sulphonic acid, o	$C_6H_4.OH.SO_3H$	174.14	$C_6H_6O_4S$
29 — — —, m	,, ,, .2H_2O	210.17	,,
30 — — —, p	,, ,,	174.14	,,

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
				125	267	1
	i.	s.	i.	130		2
						3
0.6337/15				liq.	36.15	4
0.6382/14°				liq.	27.95	5
					9.5	6
				102		7
1.19/14.5°				69	d.	8
1.619/20°					119.5—120.5 /747.3mm.	9
1.712/12.8°	i.				146.5—148	10
	1 : 100	s.	s., s. CHCl₃			11
0.8558/10°		i.	s.		175—176 /755mm.	12
	1 : 70, h.	s.		135		13
	h.s.	v.s.	v.s.	145—147		14
1.404	h.s.s.	s.s.	s.s., s. C₆H₆	205	>360	15
1.063/100°	i.	2.62 : 100/16°	s.	99—99.5, subl. 95—96	340	16
	s.	v.s.	v.s.	148—149		17
	v.s.s.	h.s.	s.	171	>360	18
0.9580/24°	s.	s.	s.	liq.	198	19
0.9395/15°	1 : 24/20°			liq.	183—185	20
		s.		liq.	228	21
		s.		liq.	180—205 /100mm.	22
		s.		2.4	244	23
		s.		− 34	171	24
1.0489/50°	5.1 : 100/25°	m.	m.	42.5—43	181	25
	h.s.s	h.s.	s.	253—255, amorph. 100		26
	s.			225		27
	v.s.	v.s.				28
	s.	s.				29
	s.	s.				30

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Phenol tricarboxylic acid, 5 : 1 : 2 : 4	$C_6H_2OH(COOH)_3$	226.09	$C_9H_6O_7$
2 — — —, 2 : 1 : 3 : 5	„	226.09	„
3 Phenoquinone	$C_6H_4O_2.2C_6H_6O$	296.22	$C_{18}H_8O_4$
4 Phenoxazine	$C_6H_4 \diagup^{NH}_{O} \diagdown C_6H_4$	183.14	$C_{12}H_9ON$
5 Phenthiazine, thio-diphenylamine	$C_6H_4 \diagup^{NH}_{S} \diagdown C_6H_4$	199.20	$C_{12}H_9NS$
6 Phenyl acetaldehyde	$C_6H_5.CH_2.CHO$	120.10	C_8H_8O
7 — acetic acid	$C_6H_5.CH_2.COOH$	136.10	$C_8H_8O_2$
8 — acetate, ethyl	$C_6H_5.CH_2.COOC_2H_5$	164.15	$C_{10}H_{12}O_2$
9 — —, methyl	$C_6H_5.CH_2.COOCH_3$	150.12	$C_9H_{10}O_2$
10 — acetic anhydride	$(C_6H_5.CH_2.CO).,O$	254.19	$C_{16}H_{14}O_3$
11 — acetyl chloride	$C_6H_5.CH_2.COCl$	154.56	C_8H_7OCl
12 — acetylene	$C_6H_5.C : CH$	102.19	C_8H_6
13 — acridine, 9	$C_6H_4 \diagup^{N}_{O} \diagdown {}^{C_6H_4}_{—C_6H_5}$	255.21	$C_{19}H_{13}N$
14 — amino ethyl alcohol	$C_6H_5.NH.(C_2H_4OH)$	137.14	$C_8H_{11}ON$
15 — — propionic acid, β a, rac.	$C_6H_5.CH_2.CH(NH_2)COOH$	165.14	$C_9H_{11}O_2N$
16 — — — —, $\beta \beta$	$C_6H_5.CH(NH_2).CH_2.COOH$	165.14	„
17 — angelic acid	$C_6H_5.CH : C(C_2H_5)COOH$	176.15	$C_{11}H_{12}O_2$
18 — anthracene, 9	$C_{14}H_9.C_6H_5$	254.21	$C_{20}H_{14}$
19 — benzene, see	Diphenyl		
20 — benzoic acid, see	Diphenyl carboxylic acid		
21 — butyric acid, a	$C_6H_5.(CH_2)_3.COOH$	164.12	$C_{10}H_{12}O_2$
22 — —, β, d	$CH_3.CH(C_6H_5).CH_2.COOH$	164.12	„
23 — —, β, l	„	164.12	„
24 — —, β, r	„	164.12	„
25 — carbylamine	$C_6H_5.NC$	103.09	C_7H_5N
26 — cinnamic acid, a	$C_6H_5.CH : C(C_6H_5)COOH$	224.17	$C_{15}H_{12}O_2$
27 — — —, β	$C_6H_5.C(C_6H_5) : CH.COOH$	224.17	„
28 — crotonic acid	$C_6H_5.CH : C(CH_3)COOH$	162.13	$C_{10}H_{10}O_2$
29 — cyanamide	$NC.NH.C_6H_5$	106.10	$C_7H_6N_2$
30 — iso-cyanate	$C_6H_5.N : C : O$	119.08	C_7H_5ON

Density $H_2O=1$.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
	1 : 200/16°	h.s.	s.s.	an. 245 d.		1
				312 d.		2
	c.s.	s.	s.	71		3
		v.s.	v.s.	148		4
	s. C_6H_6	c.s.s.	s.	180—181	371	5
1.085				liq.	205—207	6
1.0809/80°	h.s.	s.	s.	77.5—78	262—263 /751mm.	7
1.0462/15°					229	8
1.044/16°					214—216/754mm	9
			s.	72.5		10
1.1753/15°					180—183 d.	11
0.9295/20°				liq.	141.6	12
	s. C_6H_6	h.s.	s.	181—183	403—404	13
1.11/0°	v.s.s.	s.		liq.	280	14
	c.s.s.	h.v.s.s.	i.	263		15
	c.s.s.	s.s.	l.	234—235		16
	c.v.s.s.	s.		104		17
	s. C_6H_6	h.s.	s.	152—153	417	18
						19
						20
	h.s.	s.	s.	42	270—272	21
					155.5—156	22
					157.2—157.7	23
				47	270	24
0.9775/15°					165—166 d.	25
	c.s.s.	s.	s.	169—170	subl.	26
				159—161		27
	s. C_6H_6	s.	s.	74	288	28
	s.s.	s.	s.	47		29
1.092/15°					163	30

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Phenyl dihydro quinazoline	$C_6H_4 \diagup{}^{CH_2.N.C_6H_5}_{N\,:\,CH}$	208.19	$C_{14}H_{12}N_2$
2 — disulphide	$(C_6H_5)_2S_2$	218.26	$C_{12}H_{10}S_2$
3 — di tolyl methane	$(CH_3.C_6H_4)_2:CH.C_6H_5$	272.27	$C_{21}H_{20}$
4 — ether	$C_6H_5.O.C_6H_5$	170.14	$C_{12}H_{10}O$
5 — ethyl alcohol, norm.	$C_6H_5.CH_2.CH_2OH$	122.12	$C_8H_{10}O$
6 — — —, sec	$C_6H_5.CHOH.CH_3$	122.12	,,
7 — formanilide	$C_6H_5N(C_6H_5)COH$	197.16	$C_{13}H_{11}ON$
8 — glucosazone, β	$C_{18}H_{22}N_4O_4$	358.31	$C_{18}H_{22}O_4N_4$
9 — —, α	,,	358.31	,,
10 — glycine	$C_6H_5.NH.CH_2.COOH$	151.12	$C_8H_9O_2N$
11 — — carboxylic acid	$COOH.C_6H_4.NH.CH_2.COOH$	195.13	$C_9H_9O_4N$
12 — hydrazine	$C_6H_5.NH.NH_2.\tfrac{1}{2}H_2O$	117.12	$C_6H_9N_2$
13 — hydroxylamine, β	$C_6H_5.NH.OH$	109.10	C_6H_7ON
14 — isoamyl ether	$C_6H_5.O.C_5H_{11}$	164.18	$C_{11}H_{16}O$
15 — isocrotonic acid	$C_6H_5.CH:CH.CH_3.COOH$	162.13	$C_{10}H_{10}O_2$
16 — isopropyl ketone	$C_6H_5.CO.CH:(CH_3)_2$	148.15	$C_{10}H_{12}O$
17 — lactic acid, α	$C_6H_5.CHOH.COOH$	166.13	$C_9H_{10}O_3$
18 — — —, β	$C_6H_5.CHOH.CH_2.COOH$	166.13	,,
19 — malonic acid	$C_6H_5.CH:(COOH)_2$	180.11	$C_9H_8O_4$
20 — malonate, diethyl	$C_6H_5.CH:(COOC_2H_5)_2$	236.19	$C_{13}H_{16}O_4$
21 — mercaptan	$C_6H_5.SH$	110.14	C_6H_6S
22 — methyl pyrazolone	$C_{10}H_{10}N_2O$	174.15	$C_{10}H_{10}ON_2$
23 — naphthalene, α	$C_6H_5.C_{10}H_7$	204.18	$C_{16}H_{12}$
24 — —, β	,,	204.18	,,
25 — naphthylamine, α	$C_{10}H_7.NH.C_6H_5$	219.19	$C_{16}H_{13}N$
26 — —, β	,,	219.19	,,
27 — nitramine	$C_6H_5.NH.NO_2$	138.10	$C_6H_6O_2N_2$
28 — oxycrotonic acid, α	$C_6H_5.CH:CH.CHOH.COOH$	178.13	$C_{10}H_{10}O_3$
29 — oxydisulphide	$(C_6H_5)_2S_2O_2$	250.26	$C_{12}H_{10}O_2S_2$
30 — phosphine	$C_6H_5.PH_2$	110.13	C_6H_7P
31 — phosphinic acid	$C_6H_5.PO(OH)_2$	158.13	$C_6H_7O_3P$
32 — propiolic acid, δ	$C_9H_6O_2$	146.09	$C_9H_6O_2$
33 — propyl alcohol, α	$C_6H_5.CH_2.CH_2.CH_2OH$	136.14	$C_9H_{12}O$
34 — — —, β	$C_6H_5.CH_2.CHOH.CH_3$	136.14	,,
35 — — —, γ	$C_6H_5.CHOH.CH_2.CH_3$	136.14	,,
36 — — ketone	$C_6H_5.CO.C_3H_7$	136.14	$C_9H_{12}O$

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	i.	s.	s.	93		1
	i.	s.	v.s.	60—61	310	2
	v.s. CHCl₃	v.s. CS₂	v.s., v.s.	53		3
	i.	s.	s. C₆H₆	28	257	4
1.0337/21°		s. (dil.)		liq.	212	5
1.013	i.			liq.	202—204	6
		s.		73—74	210—220 in vac.	7
	v.s.s.	h.v.s.		205		8
				145		9
	s.	s.s.	v.s.s.	126—127		10
	h.s.	s.	s.	207 d.		11
1.0981/20°	h.s.	m.	m.	19.6	243.5	12
	1 : 10, h.	v.s.	v.s.	80—81		13
0.9198/21°				liq.	215	14
	h.s.s.	v.s.	v.s.	86	302	15
					220/746mm.	16
	s.			97—98		17
	s.v.s., h.m.			93		18
	s.s.	s.s.	s.s.	152—153		19
					285 d.	20
1.078/24°	i.	s.	s.	liq.	172.5	21
	h.s.	h.s.	v.s.s.	127	287/205mm.	22
	s. C₆H₆	s.	s.	0	324—325	23
	s. C₆H₆	h.s.		102—102.5	345—346	24
	s. CH₃OH	s.	s.	62	335/258mm.	25
	s. CH₃OH	s.	s.	107.5—108	395—395.5	26
				46	98	27
	s. C₆H₆	s.	s.	137		28
		h.s.	s.	45		29
1.001/15°					160—161	30
1.475	23.5 : 100/	s.		158		31
	h.s. 15°	v.s.	v.s.	136—137		32
1.008/18°	s.s.	m.	m.	liq.	212	33
					214.5—215.5	34
				liq.	235	35
0.990/15°				liq.	220—222	36

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Phenyl pyridine, α	$C_5H_4N.C_6H_5$	155.14	$C_{11}H_9N$
2 — —, β	,, ,,	155.14	
3 — —, γ	,, ,,	155.14	,,
4 — quinoline, 2	$C_9H_6N.C_6H_5$	205.17	$C_{15}H_{11}N$
5 — —, 3	,, ,,	205.17	,,
6 — —, 4	,, ,,	205.17	,,
7 — —, 6	,, ,,	205.17	,,
8 — —, 8	,, ,,	205.17	,,
9 — salicylic acid	$C_6H_5.C_6H_3(OH)COOH$	214.15	$C_{13}H_{10}O_3$
10 — sulphide	$(C_6H_5)_2S$	186.20	$C_{12}H_{10}S$
11 — thiocyanate, $iso.$	C_6H_5NCS	135.15	C_7H_5NS
12 — thioglycollic acid	$C_6H_5.S.CH_2COOH$	169.16	$C_8H_8O_2S$
13 — thiourea	$CS(NH_2)NH.C_6H_5$	152.18	$C_7H_8N_2S$
14 — tolyl	$C_6H_5.C_6H_4.CH_3$	168.16	$C_{13}H_{12}$
15 — — ketone, o	$C_6H_5.CO.C_6H_4.CH_3$	196.17	$C_{14}H_{12}O$
16 — — —, m	,, ,,	196.17	,,
17 — — —, p	,, ,,	196.17	,,
18 — urethane	$C_6H_5.NH.COOC_2H_5$	165.14	$C_9H_{11}O_2N$
19 Phenylene diacetic acid, o	$C_6H_4:(CH_2.COOH)_2$	194.13	$C_{10}H_{10}O_4$
20 — — —, m	,, ,,	194.13	,,
21 — — —, p	,, ,,	194.13	,,
22 — diamine, o	$C_6H_4(NH_2)_2$	108.11	$C_6H_8N_2$
23 — —, m	,,	108.11	,,
24 — —, p	,,	108.11	,,
25 — mercaptan, 1 : 3	$C_6H_4(SH)_2$	142.20	$C_6H_6S_2$
26 — —, 1 : 4	,,	142.20	,,
27 Phloretic acid	$C_6H_4OH.CH(CH_3).COOH$	166.13	$C_9H_{10}O_3$
28 Phloretin	$C_{15}H_{14}O_5$	274.19	$C_{15}H_{14}O_5$
29 Phloridzin	$C_{21}H_{24}O_{10}.2H_2O$	472.33	$C_{21}H_{24}O_{10}$
30 Phloroglucinol, 1 : 3 : 5	$C_6H_3(OH)_3.2H_2O$	162.11	$C_6H_6O_3$
31 — tricarboxylic ester	$C_9H_3O_3(C_2H_5)_3$	342.22	$C_{15}H_{18}O_9$
32 — triethyl ether, 1 : 3 : 5	$C_6H_3(OC_2H_5)_3$	210.22	$C_{12}H_{18}O_3$
33 — trioxime	$C_6H_3(NOH)_3$	171.13	$C_6H_9N_3O_3$
34 Phlorol	$C_2H_5.C_6H_4OH$	122.12	$C_8H_{10}O$

Density $H_2O=1$.	Water.	Solubility in—— Alcohol.	Ether.	M.P. °C.	B.P. °C.	
$>H_2O$	i.			liq.	268.5—270.5 /749mm.	1
$>H_2O$	i.	s.	s.	oil.	269—270 /749mm.	2
	h.s.			77—78	274—275	3
	s. C_6H_6	s.	s.	83—84	363	4
	v.s.s.	s.	s.	52		5
	s.s.	h.s.	s.	61—62		6
1.194/20°				110—111	260/77mm.	7
		s.s. $CHCl_3$			283/187	8
				159		9
1.12	i.	s.	s.		296	10
1.135/15°	i.	s. (abs.)	s.	- 21	218.5	11
	c.s.s.; h.s.	m.	m.	62		12
	1 : 400, c. 1 : 17, h.	5.6 : 100 /17°	s. alk.	154		13
1.015/27°				27	261—262	14
				liq.	315—316	15
1.088/17.5°	m. C_6H_6	m	m.	liq.	314—316	16
	s. C_6H_6.	s.s.	s.	60	322	17
				51—52	237—238	18
	c.s.s.	s.	s.	150		19
	s.	s.	s.	170		20
	h.s.	s.	s.	244		21
	h.s.	v.s.	v.s., s. $CHCl_3$	102—103	256—258	22
1.1389/15°	v.s.	v.s.	v.s.	61	282—284	23
	s.	s.	s.	140	267	24
				27	243	25
				98		26
	h.s.	s.	s.	128—129		27
	h.v.s.s.	h.m. acetic.	v.s.s.	253—255 d		28
1.4298/19°	h.s.	s.	i.	108		29
	s.	s.	s.	an. 217—219		30
	i.	s.s.	s.	104		31
	i.	v.s.	v.s.	43	175/24mm.	32
	v.s.s.	v.s.s.	s. $CHCl_3$, acetone	d 140		33
1.0371/0°				liq.	206.5—207.5	34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Phorone	$(CH_3)_2:C:CH.CO.CH:C:$ $(CH_3)_2$	138.16	$C_9H_{14}O$
2	Phosgene	$COCl_2$	98.93	$COCl_2$
3	Phosphenyl chloride	$C_6H_5.PCl_2$	179.03	$C_6H_5Cl_2P$
4	Phosphenylic acid	$C_6H_5.PO(OH)_2$	142.13	$C_6H_7O_2P$
5	Phospho benzene	$C_6H_5.P:P.C_6H_5$	216.22	$C_{12}H_{10}P_2$
6	Phthalamide	$C_6H_4:(CONH_2)_2$	164.12	$C_8H_8O_2N_2$
7	Phthalanil, *sym.*	$C_8H_4O_2:N.C_6H_5$	223.15	$C_{14}H_9O_2N$
8	—, *asym.*	,, ,,	223.15	,,
9	Phthalic acid, *o*	$C_6H_4:(COOH)_2$	166.09	$C_8H_6O_4$
10	Phthalate, ethyl hydrogen	$C_6H_4(COOC_2H_5)COOH$	194.13	$C_{10}H_{10}O_4$
11	—, diethyl	$C_6H_4:(COOC_2H_5)_2$	222.17	$C_{12}H_{14}O_4$
12	Phthalic acid, *m.*, *iso.*	$C_6H_4:(COOH)_2$	166.09	$C_8H_6O_4$
13	——, *p, tere.*	,, ,,	166.09	,,
14	— aldehyde	$C_6H_4:(CHO)_2$	134.09	$C_8H_6O_2$
15	——, *iso.*	,, ,,	134.09	..
16	——, *tere.*	,, ,,	134.09	,,
17	— anhydride	$C_6H_4:(CO)_2:O$	148.07	$C_8H_4O_3$
18	Phthalide	$C_6H_4:(CH_2)(CO):O$	134.09	$C_8H_6O_2$
19	Phthalimide	$C_6H_4:(CO)_2:NH$	147.09	$C_8H_5O_2N$
20	Phthalonic acid	$COOH.C_6H_4.CO.COOH$.$2H_2O$	230.12	$C_9H_6O_5$
21	Phthalonitrile, *iso.*	$C_6H_4:(CN)_2$	128.09	$C_8H_4N_2$
22	——, *tere.*	,, ,,	128.09	,,
23	Phthalophenone	$(C_6H_5)_2:C.C_6H_4.CO.O$	286.21	$C_{20}H_{14}O_2$
24	Phthalyl chloride, *o*	$C_6H_4:(COCl)_2$	202.99	$C_8H_4O_2Cl_2$
25	——, *m*	,, ,,	202.99	,,
26	——, *p*	,, ,,	202.99	
27	Physetoleic acid, see	Hypogæic acid		
28	Picoline, 2	$C_5H_4N.CH_3$	93.10	C_6H_7N
29	—, 3	,,	93.10	,,
30	—, 4	,,	93.10	,,
31	Picolinic acid	$C_5H_4N.COOH$	123.08	$C_6H_5O_2N$
32	Picramide, trinitro aniline	$C_6H_2(NO_2)_3NH_2$	228.10	$C_6H_4O_6N_4$
33	Picramic acid	$C_6H_2(NO_2)_2(NH_2)OH$	199.10	$C_6H_5O_5N_3$
34	Picric acid, see	Trinitro phenol		

Density H$_2$O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.8850/20°				28	197—200	1
1.392/18.5°	d.	d.			8	2
1.375/20°				uq.	225	3
1.475	23.5 : 100 /15°	s.	s.	158	d.	4
	i.	i., s.h. C$_6$H$_6$	i.	149—150		5
	i.	i.	i.	219—220 d.		6
	i.	s.		208	subl.	7
				125—126		8
585-1.593	18 : 100/99°	1 : 10 (abs)	0.684 :	196—199 d.		9
		15°	100/15°			10
	s.	≡		liq.	d.	
1,1286/15°					295	11
	1 : 460, h.	s.		348.5	subl	12
	c.v.s.s.	i.	i.		subl.	13
		s.		52		14
				89—90		15
	1 : 60, h.	v.s.	s.	116		16
1.527/4°	s.	s. CS$_2$		131.5	284.5	17
	h.s.	s.		75	290	18
	s. acetic.	s.	s	228—229	subl.	19
	s.	s.	s.	144.5		20
	c.s.s.	s.	s.	160—161		21
		s.s.	s.s.	222		22
	s. H$_2$SO$_4$	s.		115		23
1.4089/20°					275.4/726	24
				41	276	25
				77—78	259	26
						27
0.9526/10°				liq.	129	28
0.9726/0°	m.			liq.	144—147	29
0.9742/0°				liq.	142.5—144.5	30
	s.	s.	i.	134.5—136		31
1.762/14°	i.	i.	s. acetic.	188		32
	s.s.	s., s.ac.	s.s.	168—169		33
						34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Picryl chloride,1:3:5:2	$C_6H_2(NO_2)_3Cl$	247.54	$C_6H_2O_6N_3Cl$
2	——, 1:2:4:5	,, ,,	247.54	,,
3	Pimaric acid, d	$C_{20}H_{30}O_2$	302.34	$C_{20}H_{30}O_2$
4	——, l	,,	302.34	,,
5	——, i	,,	302.34	,,
6	Pimelic acid	$C_7H_{12}O_4$	160.13	$C_7H_{12}O_4$
7	Pinacoline	$CH_3.CO.C(CH_3)_3$	100.13	$C_6H_{12}O$
8	Pinacone	$(CH_3)_2(C.OH)_2(CH_3)_2$	118.14	$C_6H_{14}O_2$
9	Pinene, act.	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
10	— hydrochloride	$C_{10}H_{17}Cl$	172.65	$C_{10}H_{17}Cl$
11	Pinol	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
12	Pipecoline, methyl piperidine, a	$C_5H_{10}N.CH_3$	99.14	$C_6H_{13}N$
13	—,——, β	,,	99.14	,,
14	—,——, γ	,,	99.14	,,
15	Piperazine, see	Diethylene diamine		
16	Piperidine	$CH_2 \Big\langle \begin{smallmatrix} CH_2.CH_2 \\ CH_2.CH_2 \end{smallmatrix} \Big\rangle NH$	85.12	$C_5H_{11}N$
17	Piperinic acid	$C_{12}H_{10}O_4$	218.14	$C_{12}H_{10}O_4$
18	Piperonal	$(CH_2O_2)C_6H_3.CHO$	150.09	$C_8H_6O_3$
19	Piperonyl alcohol	$C_8H_8O_3$	152.10	$C_8H_8O_3$
20	Piperonylic acid	$C_8H_6O_4$	166.09	$C_8H_6O_4$
21	Piperylene	$CH_2:CH.CH_2.CH:CH_2$	68.09	C_5H_8
22	Pivalic acid	$(CH_3)_3C.COOH$	102.11	$C_5H_{10}O_2$
23	Populin, benzoyl salicin	$C_{20}H_{22}O_8.2H_2O$	426.31	$C_{20}H_{22}O_8$
24	Prehnitic acid,1:2:3:5	$C_6H_2(COOH)_4$	254.10	$C_{10}H_6O_8$
25	Prehnitole, 1:2:3:4	$C_6H_2(CH_3)_4$	134.16	$C_{10}H_{14}$
26	Propane	C_3H_8	44.08	C_3H_8
27	Propiolic acid	$CH:C.COOH$	70.03	$C_3H_2O_2$
28	— alcohol	$CH:C.CH_2OH$	56.05	C_3H_4O
29	Propionamide	$C_2H_5.CO.NH_2$	73.08	C_3H_7ON
30	Propionic acid	$C_2H_5.COOH$	74.06	$C_3H_6O_2$
31	Propionate, amyl	$C_2H_5.COO.C_5H_{11}$	144.17	$C_8H_{16}O_2$
32	—, ethyl	$C_2H_5.COO.C_2H_5$	102.11	$C_5H_{10}O_2$
33	—, methyl	$C_2H_5.COOCH_3$	88.08	$C_4H_8O_2$
34	Propionic anhydride	$(C_2H_5.CO)_2:O$	130.11	$C_6H_{10}O_3$

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	c.i., h.d.	h.s.	s.s.	83		1
				116		2
	i.	s.	s.	210—211	282/15—20	3
				140—150		4
				144—146		5
	1 : 24/20°	s.	s.	105	272/100mm.	6
0.7999/16°	v.s.s.				106	7
	h.s.	s.		35—38	171—172	8
0.865/15°	i.	s.		− 50	156.4—156.6 /757mm.	9
			i.	133.5	210	10
0.942/20°				liq.	183—184	11
0.8622/0°					116—117 /714mm.	12
0.8635/0°	v.s.			liq.	125—126	13
0.8674/0°	s.			liq.	126.5—128	14
						15
0.8615/20°	m.	s.		− 17	106/759mm.	16
	i.	1 : 50, h.	s.	216—217		17
	h.s.	s.	m.	37	263	18
	h.s.	m.	m.	51		19
	h.s.s.	h.s.	s.s.	227—229		20
				liq.	40—41	21
0.905/50°	s.			35.3—35.5	163.7—163.8	22
	1 : 42/100°	v.s.		180		23
	s.			237—250		24
				− 4	204	25
0.613/−25°		6 : 1 vol.		− 195	− 38	26
	s.	s.	s.	5	140—145, d. 154	27
0.9628/21°	s.			− 17	114—115	28
1.0335				80	213	29
0.9871/19.9°	m.	s.	s.	− 19.3	140.5	30
0.887/0°				liq.	160.2	31
0.8964/16°		s.		− 72.6	99.1	32
0.917/18.5°					79.6	33
1.0169/15°	i.			liq.	165.8	34

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Propionitrile	$C_2H_5.CN$	55.07	C_3H_5N
2 Propionyl chloride	$C_2H_5.COCl$	92.52	C_3H_5OCl
3 — formic acid	see Keto-butyric acid		
4 Propyl alcohol, norm.	$CH_3.CH_2.CH_2OH$	60.08	C_3H_8O
5 ——, *iso.*	$CH_3.CHOH.CH_3$	60.08	,,
6 — aldehyde	$CH_3.CH_2.CHO$	58.06	C_3H_6O
7 — amine, norm.	$C_2H_5.CH_2.NH_2$	59.10	C_3H_9N
8 ——, *iso.*	$(CH_3)_2.CH.NH_2$	59.10	,,
9 — benzene, norm.	$C_6H_5.C_3H_7$	120.14	C_9H_{12}
10 ——, cumene	$C_6H_5.CH:(CH_3)_2$	120.14	,,
11 — carbylamine, *iso.*	$(CH_3)_2.CH.NC$	69.09	C_4H_7N
12 — chloride, norm.	C_3H_7Cl	78.53	C_3H_7Cl
13 ——, *iso.*	$(CH_3)_2:CHCl$	78.53	,,
14 — cyanide, norm.	C_3H_7CN	69.09	C_4H_7N
15 ——, *iso.*	$(CH_3)_2:CH.CN$	69.09	,,
16 — mercaptan	$C_3H_7.SH$	76.14	C_3H_8S
17 — nitrolic acid	$CH_3.CH_2.C(NO_2)NOH$	118.08	$C_3H_6O_3N_2$
18 — pyridine, α	$C_3H_7.C_5H_4N$	121.14	$C_8H_{11}N$
19 ——, α *iso.*	,, ,,	121.14	,,
20 ——, γ *iso.*	,, ,,	121.14	,,
21 — sulphide	$(C_3H_7)_2:S$	118.20	$C_6H_{14}S$
22 — thiocyanate, *iso.*	$C_3H_7.NCS$	101.15	C_4H_7NS
23 Propylene	$CH_3.CH:CH_2$	42.06	C_3H_6
24 — bromide	$CH_3.CHBr.CH_2Br$	210.90	$C_3H_6Br_2$
25 — ether	C_3H_6O	58.06	C_3H_6O
26 — glycol, tri-methylene alcohol	$CH_2OH.CH_2.CH_2OH$	76.08	$C_3H_8O_2$
27 ——, propylene alcohol	$CH_3.CHOH.CH_2OH$	76.08	,,
28 Protocatechuic acid,	see Dihydroxy benzoic acid		
29 — aldehyde, 1:3:4	$C_6H_3(OH)_2CHO$	138.06	$C_7H_6O_3$
30 Pseudo cumene, 1:2:4	$C_6H_3(CH_3)_3$	120.14	C_9H_{12}
31 — cumidine, 1:2:4:5	$(CH_3)_3C_6H_2.NH_2$	135.16	$C_9H_{13}N$
32 Pulegone	$C_{10}H_{16}O$	152.18	$C_{10}H_{16}O$
33 Purine	$$\begin{array}{c} N = CH \\ | \qquad | \\ CH \quad C.NH \diagdown \\ \| \qquad \| \qquad\quad OH \\ N - C.N \diagup \end{array}$$	120.10	$C_5H_4N_4$
34 Purpurin, see	Trihydroxy anthraquinone		

Density H₂O=1.	Solubility in— Water.	Alcohol.	Ether.	M.P °C.	B.P. °C.	
0.801/0°	s.			− 103.5	98	1
1.0646/20°					80	2
						3
0.8066/15°	s.	s.	s.	liq.	97.2	4
0.7887/20°	s.	s.	s.	liq.	82.7	5
0.8066/20°	1 : 5/20°				49.5/740	6
0.7168/20°	s.			liq.	49	7
0.690/18°	m.			liq.	32—32.5	8
0.881/0°	i.	s.	s.		157—158	9
0.8798/0°	i.	s.	s.	− 75.1	152.5—153.5	10
				liq.	87	11
0.891/18°					44/744mm.	12
0.8588/20°					37	13
0.795/12.5°				liq.	118.5	14
				liq.	107—108	15
	v.s.s.				67	16
	v.s.	s.	v.s	74—75		17
$<\text{H}_2\text{O}$				liq.	165—168	18
0.9342/0°	s.s.				158—159	19
0.9439/0°					177—178	20
0.814/17°				liq.	141.5—142.5	21
					137—137.5	22
1.498	12 : 1 vol.				− 37	23
1.9463/17°					130	24
	s.	s.	s.	liq.	35	25
1.0526/18°	m.	m.	1 : 12.5 vol.	liq.	216	26
1.051/0°	m.			liq.	188—189	27
						28
	1 : 20, c.	v.s.	v.s.	153—154		29
0.8810/15°					167—167.6	30
				64	234—235	31
0.932/20°				liq.	221.2	32
	v.s.	s.	s. toluene	211—212		33
						34

P

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Purpuroxanthene,	see Dihydroxy anthraquinone		
2 Pyrazine	$OH \underset{N:CH}{\overset{CH:N}{<>}} OH$	80.07	$C_4H_4N_2$
3 Pyrazole	$OH:N \underset{CH:CH}{\overset{|}{<}} NH$	68.07	$C_3H_3N_2$
4 Pyrazoline	$CH_2.CH_2.CH:N.NH$	70.08	$C_3H_6N_2$
5 Pyrazolone	$CO.CH_2.CH:N.NH$	84.07	$C_3H_4ON_2$
6 Pyrene	$C_{16}H_{10}$	202.16	$C_{16}H_{10}$
7 Pyridazine	$OH \underset{N:N}{\overset{CH.CH}{<>}} CH$	80.07	$C_4H_4N_2$
8 Pyridine	C_5H_5N	79.08	C_5H_5N
9 — carboxylic acid, a	see Picolinic acid		
10 — — —, β	see Nicotinic acid		
11 — — —, γ iso-nicotinic acid	$C_5H_4N.COOH$	123.08	$C_6H_5O_2N$
12 — dicarboxylic acid, 1:3:4, cinchomeronic acid	$C_5H_3N:(COOH)_2$	167.09	$C_7H_5O_4N$
13 — — —, 1:2:5, iso-cinchomeronic acid	,, ,, ($\frac{1}{2}$ or $1\frac{1}{2} H_2O$)	167.09	,,
14 — — —, 1:2:6, dipicolinic acid	,, ,, ($1\frac{1}{2} H_2O$)	167.09	,,
15 — — —, 1:3:5, dinicotinic acid	,, ,,	167.09	,,
16 — — —, 1:2:4, lutidinic acid	,, ,, (H_2O)	167.09	,,
17 — — —, 1:2:3, quinolic acid	,, ,,	167.09	,,
18 — penta carboxylic acid	$C_5N(COOH)_5$ ($2—3H_2O$)	299.10	$C_{10}H_5O_{10}N$
19 — tricarboxylic acid, 1:2:3:4	$C_5H_2N(COOH)_3.1\frac{1}{2}H_2O$	238.12	$C_8H_5O_6N$
20 — — —, 1:2:4:5	,, ,, .$2H_2O$	247.12	,,
21 — — —, 1:3:4:5	,, ,, .$3H_2O$	265.14	,,
22 — — —, 1:2:4:6	,, ,, .$2H_2O$	247.12	,,
23 — — —, 1:2:3:5	,, ,, .$2H_2O$	247.12	,,
24 — — —, 1:2:3:6	,, ,, .$2H_2O$	247.12	,,

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
						1
	s.	s.	s., s. ao.	47	118/768.4	2
	o.s.	s.	s.	69	186—188	3
	m.	m.	s.s.	liq.	144	4
	s.	v.s.	v.s.s.	165		5
	v.s. OS_2	1.37 : 100/16°	v.s.	147	>360	6
1.1070/20°	m.	s.	s., s. ao.	− 3	208	7
0.9893/15°	m.		− 42	115.5		8
						9
						10
	s.s.	s.s. C_6H_6	v.s.s.	299 under pressure		11
	h.v.s.s.	s.s.	i.	258—259		12
	h.s.	i.	i.	236		13
	h.s.	v.s.s		226		14
	v.s.s.			323		15
	h.v.s.	h.v.s.	l.	237		16
	1 : 183/65°	s.s.	v.s.s.	190—195		17
	v.s.		v.s.s.	d. 220		18
	1 : 83.9 /15°	s.s.	v.s.s.	249—250		19
	h.s.	h.v.s.s.	i.	235		20
	h.s.			261 d.		21
	s.		s.s.	227 d.		22
	s.s.	s.		323		23
	v.s.		i.	>100	d. 130	24

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Pyrimidine	$OH\begin{array}{c} CH.CH \\ \\ N:CH \end{array}N$	80.07	$C_4H_4N_2$
2	Pyrocatechol, see	Dihydroxy benzene		
3	Pyrogallol, 1 : 2 : 3	$C_6H_3(OH)_3$	126.08	$C_6H_6O_3$
4	— carboxylic acid, 1 : 2 : 3 : 4	$C_6H_2(OH)_3.COOH.\tfrac{1}{2}H_2O$	176.09	$C_7H_6O_5$
5	—dimethyl ether, 2 : 1 : 3	$C_6H_3(OH)(OCH_3)_2$	154.12	$C_8H_{10}O_3$
6	— triethyl ether, 1 : 2 : 3	$C_6H_3(OC_2H_5)_3$	210.22	$C_{12}H_{18}O_3$
7	Pyro mellitic acid, 1 : 2 : 4 : 5	$C_6H_2(COOH)_4.H_2O$	272.12	$C_{10}H_6O_9$
8	— mucic acid	$C_4H_3O.COOH$	112.16	$C_5H_4O_3$
9	— — —, iso.	,, ,, .2H_2O	148.09	,,
10	— racemic acid	$CH_3.CO.COOH$	88.05	$C_3H_4O_3$
11	— tartaric acid, methyl succinic acid	$CH_3.CH(COOH)CH_2.COOH$	132.09	$C_5H_8O_4$
12	— terebic acid	$C_5H_9.COOH$	114.11	$C_6H_{10}O_2$
13	— tritartaric acid	$C_4H_4(CH_3)_2O.COOH$	140.10	$C_7H_8O_3$
14	Pyrone, γ	$CO\begin{array}{c} CH:CH \\ \\ CH:CH \end{array}O$	96.06	$C_5H_4O_2$
15	— a-carboxylic acid	$C_5H_3O_2.COOH$	140.06	$C_6H_4O_4$
16	Pyroxylin	$C_{12}H_{14}(ONO_2)_6O_4$	594.23	$C_{12}H_{14}O_{22}N_6$
17	Pyrrole	$\begin{array}{c} CH:CH \\ \\ CH:CH \end{array}NH$	67.07	C_4H_5N
18	— a-carboxylic acid	$C_4H_4N.COOH$	118.05	$C_5H_5O_2N$
19	Pyrrolidine	$(CH_2)_4:NH$	71.10	C_4H_9N
20	Pyrroline	$\begin{array}{c} CH.CH_2 \\ \\ CH.CH_2 \end{array}NH$	69.09	C_4H_7N
21	Quercetin	$\begin{array}{c} (OH)_2 \\ C_6H_2 \\ \end{array}\begin{array}{c} O.C.C_6H_3(OH)_2 \\ \\ OC.C(OH) \end{array}$	302.16	$C_{15}H_{10}O_7$
22	Quercite	$C_6H_{12}O_5$	164.13	$C_6H_{12}O_5$
23	Quercitrin	$C_{21}H_{22}O_{12}.2H_2O$	502.31	$C_{21}H_{22}O_{12}$
24	Quinaldine	$C_9H_6N.CH_3$	143.13	$C_{10}H_9N$
25	Quinazine, see	Quinoxaline		

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	s.	s.		20—22	123.5—124 /762mm.	1
						2
1.463/40°	44 : 100 /13°	s.	s.	132	292—294 /730mm.	3
	v.s.	s.	s.	195—200	subl.	4
	s.			52	252	5
				39		6
	14.2 : 100 /16°	v.s.		275		7
	1 : 28/15°	s.	s.	131—132	subl.	8
	s.	v.s.	s.	87	102/15mm	9
1.288/18°	m.	m.	m.	13.6	165	10
1.410	1 :1.5/20°	v.s.	v.s.	112	d.	11
1.006/26°	s.	s.	s.	46	207	12
						13
	v.s.			32.5	210—215	14
	s.s.			d.250		15
	s.s. acetone	i.	i.	expl.		16
0.9481/20°	i.	v.s.	v.s.	liq.	126.2	17
	s.	s.	s.	d. 191.5		18
0.879/0°	m.			liq.	87.5—88.5	19
0.852/22.5°						
0.9027/20°	v.s.			liq.	90—91	20
1.5845/13°	h.s.s.	1 : 18.2, h.	v.s.s.	310—312		21
	s.	h.s		225	d.	22
	h.s.s.	h.s.	s.s			23
1.0646/20°		s.			246—247	24
						25

	Name.	Formula.	Formula Weight.	Empirical Formula
1	Quinazolone	$C_6H_4\begin{array}{l}CH:N\\ \\N:CH\end{array}$	130.11	$C_8H_6N_2$
2	Quinhydrone	$C_{12}H_{10}O_4$	218.14	$C_{12}H_{10}O_4$
3	Quinic acid	$C_6H_7(OH)_4COOH$	192.13	$C_7H_{12}O_6$
4	Quininic acid	$C_{11}H_9O_3N$	203.14	$C_{11}H_9O_3N$
5	Quinitol, cis. 1:2	$C_6H_4:(OH)_2(H_6)$	116.13	$C_6H_{12}O_2$
6	—, trans. 1:2	,, ,,	116.13	,,
7	—, cis. 1:3	,, ,,	116.13	,,
8	—, cis. 1:4	,, ,,	116.13	,,
9	—, trans. 1:4	,, ,,	116.13	,,
10	—, isom. 1:4	,, ,,	116.13	,,
11	Quinizarin, see	Dihydroxy anthraquinone		
12	Quinoline	$C_6H_4\begin{array}{l}CH:CH\\ \\N:CH\end{array}$	129.11	C_9H_7N
13	—, iso.	C_9H_7N	129.11	,,
14	Quinolinic acid, 1:2:3	$C_5H_3N(COOH)_2$	167.09	$C_7H_5O_4N$
15	Quinone, 1:4	$C_6H_4O_2$	108.06	$C_6H_4O_2$
16	— chlorimide	$O.C_6H_4.N.Cl$	141.53	C_6H_4ONCl
17	— dichlorimide	$C_6H_4(:N.Cl)_2$	175.00	$C_6H_4N_2Cl_2$
18	— di-imine	$NH:C_6H_4:NH$	106.09	$C_6H_6N_2$
19	— dioxime	$C_6H_4(:NOH)_2$	138.10	$C_6H_6O_2N_2$
20	Quinoxaline	$C_6H_4\begin{array}{l}N\\ \\N:CH\end{array}$	130.11	$C_8H_6N_2$
21	Raffinose	$C_{18}H_{32}O_{16}.5H_2O$	594.43	$C_{18}H_{32}O_{16}$
22	Resorcinol, see	Dihydroxy benzene		
23	— methyl ether	$OH.C_6H_4.OCH_3$	124.10	$C_7H_8O_2$
24	Resorcylic acid, 3:5:1	$C_6H_3(OH)_2COOH$ $(1\frac{1}{2}H_2O)$	154.08	$C_7H_6O_4$
25	—, 2:4:1	,, ,, $(3H_2O)$	154.08	,,
26	Retene	$C_{18}H_{18}$	234.23	$C_{18}H_{18}$
27	Rhamnite	$CH_3.(CHOH)_4.CH_2OH$	166.14	$C_6H_{14}O_5$
28	Rhamnose	$CH_3(CHOH)_4CHO.H_2O$	182.15	$C_6H_{12}O_5$
29	Rhodizonic acid	$C_6(OH)_2O_4$	170.05	$C_6H_2O_6$
30	Ricinoleic acid	$C_{18}H_{34}O_3$	298.36	$C_{18}H_{34}O_3$
31	Roccellic acid	$C_{15}H_{30}(COOH)_2$	300.34	$C_{17}H_{32}O_4$
32	Rosaniline	$C_{20}H_{21}N_3O$	319.24	$C_{20}H_{21}ON_3$

Density H$_2$O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
				48—48.5	243/772mm	1
	h.s.	s.	s.	171	subl.	2
	1 : 2.5/9°	v.s.s.	v.s.s.	162	d.	3
	s.s.	s.s.	v.s.s.	d. 280		4
	s.	s.	v.s.s.	75—76	225	5
				99—100	225	6
				65		7
				102		8
				140		9
					218—225	10
						11
1.0944/20°		s.	s. CS$_2$	− 19.5	238	12
1.0986/20°		s.	s.	− 24.6	240/750mm	13
	6.5 : 183	s.s.	v.s.s	190—195	d.	14
1.307-1.318	h.s.	s.	s.	115.7	subl.	15
	h.s.	s.	h.s.	84.7—85	d.	16
	h.s.s.	h.s.	v.s.	d. 124		17
				124 d.		18
	s. conc. NH$_3$				d. 240	19
	m.	m.	m.	27	225—226	20
	1 : 7/20°, h.m.	v.s.s.		an. 118—119		21
						22
	s.s.	s.s.	s.s.	liq.	243—244	23
	h.v.s.	s.	s.	232—233		24
	1 : 381/17°	s.	s.	215		25
1.13/16°		69 : 100/78°	v.s.	98	390	26
	v.s.	v.s.	s.s. CHCl$_3$	121		27
1.4708/20°	60 : 100/20°	s.		92—93, an. 122—126		28
		i.		d.		29
		m.	m.	16—17	250/15mm	30
	l.	s.	s.	132		31
	s.s.	s.	i.			32

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Rosinduline	$HN : C_{10}H_5 \diagdown{}^{N}_{N.C_6H_5} \diagup C_6H$,	321.26	$C_{22}H_{15}N_3$
2	Rosolic acid	$C_{20}H_{16}O_3$	304.23	$C_{20}H_{16}O_3$
3	Rubeanhydride	$NH_2.CS.CS.NH_2$	120.18	$C_2H_4N_2S_2$
4	Ruberythric acid	$C_{26}H_{28}O_{14}$	564.35	$C_{26}H_{28}O_{14}$
5	Rufigallic acid	$C_{14}H_8O_8.2H_2O$	340.16	$C_{14}H_8O_8$
6	Rufiopin	$C_{14}H_8O_6$	273.13	$C_{14}H_8O_6$
7	Rufol, see	Dihydroxy anthracene		
8	Saccharic acid	$C_4H_4(OH)_4(COOH)_2$	210.11	$C_6H_{10}O_8$
9	Saccharin	$C_6H_4 \diagup{}^{CO}_{SO_2} \diagdown NH$	183.15	$C_7H_5O_3NS$
10	Safrol	$CH_2:O_2:C_6H_3.CH_2.CH:CH_2$	162.13	$C_{10}H_{10}O_2$
11	—, iso.	$CH_2:O_2:C_6H_3.CH:CH.CH_3$	162.13	,,
12	Salicin	$C_{13}H_{18}O_7$	286.21	$C_{13}H_{18}O_7$
13	Salicyl aldehyde, see	Hydroxy benzaldehyde		
14	— amide	$C_6H_4OH.CONH_2$	137.10	$C_7H_7O_2N$
15	— anilide	$C_6H_4OH.CONH.C_6H_5$	213.16	$C_{13}H_{11}O_2N$
16	Salicylic acid, see	Hyroxy benzoic acid, o		
17	Salicylate, ethyl	$C_6H_4OH.COO.C_2H_5$	166.13	$C_9H_{10}O_3$
18	—, methyl	$C_6H_4OH.COO.CH_3$	152.10	$C_8H_8O_3$
19	—, phenyl	$C_6H_4OH.COO.C_6H_5$	214.15	$C_{13}H_{10}O_3$
20	Salicylic anhydride	$(C_6H_4)_2O_2(CO)_2$	240.13	$C_{14}H_8O_4$
21	Saligenin	$C_6H_4OH.CH_2OH$	124.10	$C_7H_8O_2$
22	Santalic acid	$C_{15}H_{14}O_5$	274.19	$C_{15}H_{14}O_5$
23	Santonin	$C_{15}H_{18}O_3$	246.22	$C_{15}H_{18}O_3$
24	Sarcosine	$NH.CH_3.CH_2.COOH$	89.08	$C_3H_7O_2N$
25	Sebacic acid	$COOH.(CH_2)_8.COOH$	202.19	$C_{10}H_{18}O_4$
26	Selenium di-ethyl	$(C_2H_5)_2Se$	137.3	$C_4H_{10}Se$
27	— di-methyl	$(CH_3)_2Se$	109.3	C_2H_6Se
28	Semicarbazide	$NH_2.CO.NH.NH_2$	75.08	CH_5ON_3
29	Serin	$C_2H_3(OH)(NH_2)COOH$	105.08	$C_3H_7O_3N$
30	Silico-acetic acid	$CH_3.SiOOH$	76.1	OH_4O_2Si
31	— benzoic acid	$C_6H_5.SiOOH$	138.1	$C_7H_8O_2Si$
32	— heptane	$(C_2H_5)_3SiH$	116.3	$C_6H_{16}Si$
33	Silicon phenyl trichloride	$C_6H_5.SiCl_3$	211.6	$C_6H_5Cl_3Si$
34	— — tri-ethyl	$C_6H_5.Si(C_2H_5)_3$	192.3	$C_{12}H_{20}Si$
35	— tetra-ethyl	$(C_2H_5)_4Si$	144.0	$C_8H_{20}Si$
36	— — methyl	$(CH_3)_4Si$	88.3	$C_4H_{12}Si$

Density H₂O=1.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
	i.	s.	s.	198—199		1
	v.s.s.	h.v.s.	s.	d.		2
	v.s.s.	v.s.	v.s.			3
	h.s.	s.s.	s.s.	258—260		4
	h.s.s.	s.s	s.s.	subl.		5
	h.s.s.	s.	s.s.	subl.	d	6
						7
	v.s.	s.	s.s.			8
	0.43 : 100/25°	v.s.	v.s. xylene	220 d		9
1.114/0° (liq.)	i.	s.		8	233	10
	i.	s.			251	11
1.426— 1.434/26°	1 : 28/15°	s.	i.	201	d.	12
						13
	s.s.		m.	142	ubl.	14
	h.s.s.	s.	1 : 2/15°	134—135		15
						16
1.1843/20°				1.3	231.5	17
1.182/16°	s.s.	s.		− 8.3	224	18
		h.v.s.	s.	42	173/12mm	19
	i.	s.	s.	200—201	d.	20
1.1613/25°	1 : 15/22°, h.m.	v.s.	v.s.	86	subl.	21
	s.	s.	v.s. s. C₆H₆	104		22
1.1866	v.s.s.	s.	s., s. CHCl₃	169—170	subl. d.	23
	s.s.	s.s.		210—215		24
	h.s.s.	s.	s.	133—133.5	294.5/100	25
>H₂O	1 : 50/100°		v.s.	liq.	108	26
>H₂O				liq.	58.2	27
	s.	s. C₆H₆	s. CHCl₃	96		28
	1 : 24/20°	i.	i.	246 d.		29
	i.					30
	i.		s.	92		31
0.751/··			s.	liq.	107	32
	d.	d.		liq.	197	33
0.9042/0°	i.		s.	liq.	230	34
0.8341/0°	i.		s.		153	35
<H₂O				liq.	26—27	36

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Skatole, see	Methyl indol.		
2	Sorbic acid	$C_5H_7.COOH$	112.09	$C_6H_8O_2$
3	Sorbite	$C_6H_{14}O_6.\frac{1}{2}H_2O$	191.15	$C_6H_{14}O_6$
4	Sorbose	$C_6H_{12}O_6$	180.13	$C_6H_{14}O_6$
5	Stearic acid	$C_{17}H_{35}.COOH$	284.38	$C_{18}H_{36}O_2$
6	Stearin	$C_3H_5(C_{18}H_{35}O_2)_3$	891.17	$C_{57}H_{110}O_6$
7	Stearolic acid	$C_{17}H_{31}.COOH$	280.35	$C_{18}H_{32}O_2$
8	Stearone	$C_{35}H_{70}O$	506.74	$C_{35}H_{70}O$
9	Stearoxylic acid	$C_{18}H_{32}O_4$	312.35	$C_{18}H_{32}O_4$
10	Stilbene	$C_6H_5.CH:CH.C_6H_5$	180.17	$C_{14}H_{12}$
11	Styracine	$C_8H_7.COO.C_9H_9$	264.22	$C_{18}H_{16}O_2$
12	Styroline	$C_6H_7.CH:CH_2$	104.10	C_8H_8
13	Suberane, see	Cyclo-heptane		
14	Suberic acid	$C_6H_{12}(COOH)_2$	174.15	$C_8H_{14}O_4$
15	Suberone, see	Cyclo-heptanone		
16	Succinamide	$C_2H_4:(CONH_2)_2$	116.10	$C_4H_8O_2N_2$
17	Succinic acid	$C_2H_4:(COOH)_2$	118.07	$C_4H_6O_4$
18	— —, iso.	$CH_3.CH:(COOH)_2$	118.07	
19	Succinate, calcium	$C_4H_4O_4Ca$	156.12	$C_4H_4O_4Ca$
20	—, ferrous, basic	$(C_4H_4O_4)FeOH$	188.90	$C_4H_5O_5Fe$
21	—, ethyl	$C_2H_4:(COOC_2H_5)_2$	174.15	$C_8H_{14}O_4$
22	—, methyl	$C_2H_4:(COOCH_3)_2$	146.11	$C_6H_{10}O_4$
23	Succinic anhydride	$C_2H_4:(CO)_2:O$	100.05	$C_4H_4O_3$
24	— aldehyde, α	$C_2H_4:(CHO)_2$	86.07	$C_4H_6O_2$
25	— —, β	,, ,,	86.07	,,
26	— —, γ	,, ,,	86.07	,,
27	— —, δ	,, ,,	86.07	,,
28	— —, ε	,, ,,	86.07	,,
29	— nitrile	$C_2H_4:(CN)_2$	80.07	$C_4H_4N_2$
30	Succinimide	$C_2H_4:(CO)_2:NH.H_2O$	117.09	$C_4H_4O_2N$
31	Succinyl chloride	$C_2H_4:(COCl)_2$	154.97	$C_4H_4O_2Cl_2$
32	Sucrose, see	Cane sugar		
33	Sulphanilic acid, see	Amino benzene sulphonic acid		
34	Sulpho acetic acid	$CH_2(SO_3H)COOH.1\frac{1}{2}H_2O$	167.13	$C_2H_6O_6S$
35	Sulphonal	$(CH_3)_2:C:(SO_2.C_2H_5)_2$	228.28	$C_7H_{16}O_4S_2$
36	Sylvan, see	Methyl furfurane		
37	Sylvestrine	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
38	Tannic acid	$C_{14}H_{10}O_9$	322.15	$C_{14}H_{10}O_9$

Density $H_2O=1$.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
						1
	h.s.	s.	s.	134.5	228 d.	2
	s.	h.s.		110—111		3
1.654/15°	v.s.	h.s.s		154	..	4
0.8521/69.5°	i.	h.s.		69.3	291/100mm.	5
0.9425/65.5°	i.	h.s.	s.	71.2		6
	i.	h.s.	s.	48	260	7
0.7979	i.	h.s.s.	s.s.	87.8		8
	i.	h.s.	s.s.	86		9
0.9707/119°		h.s.	s.	124—125	306—307	10
	i.	s.	s., s. OHCl₃	44		11
0.9074/20°	i.	m.	s.	liq.	145—146	12
						13
	h.s.	s.	v.s.s.	140	300	14
						15
	h.s.	i.	i.	90		16
1.552	120 : 100, h.	7 : 100	s.s.	184—185	235	17
1 455	1 : 1.5/15°	s	s.	130 d.		18
	s.s.		i.			19
	s.s.		i. acetic.	d 180		20
1.0465/15°	i.			− 20.8	216.5	21
1.1611/15°				18.5	195.2	22
	s.s.	s.	v.s.s.	119.6	261	23
	s.	s.	s.	169—170		24
					169/761mm.	25
				64		26
				130—140		27
				90—100 d.		28
0.9848/63.1°				54.5	158—160/20mm	29
	s.	s.		125—126	287—288	30
1.4123/15°				17	190	31
						32
						33
	s.			75	subl.	34
	h.s.	1 : 2, h.	s.s.	125—126	300 d.	35
						36
0.851/16°				liq.	176—177	37
	s.	s.s.	v.s.s.	d		38

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Tartaric acid, dextro	$COOH.(CHOH)_2.COOH$	150.07	$C_4H_6O_6$
2	—, laevo	,, ,,	150.07	,,
3	—, racemic	,, ,, $.H_2O$	168.09	,,
4	—, meso	,, ,, $.H_2O$	168.09	,,
5	Tartrate, potassium	$C_4H_4O_6K_2(\frac{1}{2}H_2O)$	226.25	$C_4H_4O_6K$
6	—, hydrogen	$C_4H_5O_6K$	188.16	$C_4H_5O_6K$
7	—, antimonyl	$C_4H_4O_6K.SbO(\frac{1}{2}H_2O)$	323.35	$C_4H_4O_6KSb$
8	—, sodium, Rochelle salt	$C_4H_4O_6KNa(4H_2O)$	210.15	$C_4H_4O_6KNa$
9	—, calcium	$C_4H_4O_6Ca(H_2O)$	188.12	$C_4H_4O_6Ca$
10	—, di-ethyl	$C_4H_4O_6(C_2H_5)_2$	206.15	$C_8H_{14}O_6$
11	—, ethyl	$C_4H_5O_6.C_2H_5$	178.11	$C_8H_{10}O_6$
12	Tartronic acid	$CHOH:(COOH)_2.1\frac{1}{2}H_2O$	147.07	$C_3H_4O_5$
13	Taurine	$C_2H_4NH_2.SO_3H$	125.14	$C_2H_7O_3NS$
14	Taurocholic acid	$C_{26}H_{45}NO_7S$	515.56	$C_{26}H_{45}O_7NS$
15	Tellurium di-ethyl	$(C_2H_5)_2Te$	185.6	$C_4H_{10}Te$
16	—dimethyl	$(CH_3)_2Te$	157.6	C_2H_6Te
17	Teraconic acid	$(CH_3)_2:C:C(COOH)CH_2.COOH$	158.12	$C_7H_{10}O_4$
18	Terebene	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
19	Terebentylic acid	$C_8H_{10}O_2$	138.12	$C_8H_{10}O_2$
20	Terebic acid	$C_7H_{10}O_4$	158.12	$C_7H_{10}O_4$
21	Terpenylic acid	$C_8H_{12}O_4.H_2O$	190.16	$C_8H_{12}O_4$
22	Terpinene, α	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
23	—, β	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
24	Terpineol, α	$C_{10}H_{17}OH$	154.19	$C_{10}H_{18}O$
25	Terpin hydrate	$C_{10}H_{18}(OH)_2.H_2O$	190.23	$C_{10}H_{20}O_2$
26	Terpinolene	$CH_3.C\genfrac{}{}{0pt}{}{OH.CH_2}{CH_2.CH_2}C:C\genfrac{}{}{0pt}{}{CH_3}{CH_3}$	136.18	$C_{10}H_{16}$
27	Tetra-brom-benzene, 1:2:3:5	$C_6H_2Br_4$	393.73	$C_6H_2Br_4$
28	—, 1:2:4:5	,,	393.73	,,
29	— benzoquinone, 3:4:5:6	$C_6Br_4O_2$	423.71	$C_6O_2Br_4$
30	—, 2:3:5:6	,,	423.71	,,
31	— chlor aniline, 2:3:4:5	$C_6HCl_4.NH_2$	230.90	$C_6H_3Cl_4N$
32	—, 2:3:5:6	,,	230.90	,,
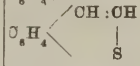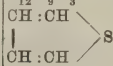
Density H₂O=1.	Water.	Solubility in Alcohol.	Ether.	M.P. °C.	B.P. °C.	
1.76	139 : 100/20°	1 : 5	i.	168—170		1
1 76	139 : 100/20°	s.	i.	169—170		2
1.78 an.	20.6 : 100/20°	s.s.		205		3
1.67	v.s.			140		4
1.975	s.	s.s.		an. 180		5
1.956	h.s.	s.s.				6
2.6	v.s.	i.				7
1.77	s.s.		s. ac., alk			8
	v.s.s.	i.		an. 100	i. 200	9
1.2059/20°	i.	s.	s.	liq.		10
				90		11
		s.	s.	subl. 110—120	d. 186	12
	h.s.	i.	i.	d. 240		13
	s.	s.	s.s.	180		14
				liq.	137—138	15
	i.			liq.	s2	16
	s.	s.	s.	161—163 d.		17
0.876/0°				liq.	160	18
	h.s.	s.	s.	90	250	19
	h.s.	s.	s.	174		20
	s.	s.	s.	an. 90	d. 176/751mm.	21
					173—174	22
						23
0.9357/20°	i.	s.	s.	35	217.7	24
	h.s.	s.		an. 105	258	25
	h.s.	s.	s.	174	d.	26
		h.v.s.	s.	98.5	329	27
3.027/20°		s.		177—178		28
	i., s. C₆H₆	h.s.	s.s.	150—151		29
					300	30
		s.	s.	118		31
				90		32

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Tetra chlor benzene, 1:2:3:4	$C_6H_2Cl_4$	215.89	$C_6H_2Cl_4$
2	———, 1:2:3:5	,,	215.89	,,
3	———, 1:2:4:5	,,	215.89	,,
4	——ethane, $\alpha\,\alpha\,\alpha\,\beta$	$CH_2Cl.CCl_3$	167.87	$C_2H_2Cl_4$
5	———, $\alpha\,\alpha\,\beta\,\beta$	$CHCl_2.CHCl_2$	167.87	,,
6	—— ether	$CCl_3.CHCl.O.C_2H_5$	211.91	$C_4H_6OCl_4$
7	—— hydroquinone	$C_6Cl_4(OH)_2$	247.89	$C_6H_2O_2Cl_4$
8	—— phthalic acid	$C_6Cl_4:(COOH)_2$	303.90	$C_8H_2O_4Cl_4$
9	—— anhydride	$C_6Cl_4:(CO)_2:O$	285.88	$C_8O_3Cl_4$
10	Tetradecane	$C_{14}H_{30}$	198.31	$C_{14}H_{30}$
11	Tetra decylene	$C_{14}H_{28}$	196.29	$C_{14}H_{28}$
12	— ethyl ammonium hydroxide	$(C_2H_5)_4N.OH$	219.28	$C_8H_{21}ON$
13	—— benzene, 1:2:3:4	$C_6H_2(C_2H_5)_4$	190.25	$C_{14}H_{22}$
14	———, 1:2:4:5	,,	190.25	,,
15	— hydro benzene, 1:2:3:4	$C_6H_6.H_4$	82.11	C_6H_{10}
16	—— benzoic acid	$CH_2\Big\langle{{CH_2.CH}\atop{CH_2.CH_2}}\Big\rangle C.COOH$	126.12	$C_7H_{10}O_2$
17	—— naphthalene, 1:2:3:4	$C_{10}H_8.H_4$	132.15	$C_{10}H_{12}$
18	— — naphthol, α	$OH.C_6H_3\Big\langle{{CH_2.CH_2}\atop{CH_2.CH_2}}$	148.15	$C_{10}H_{12}O$
19	——β naphthylamine, 1:2:3:4	$C_{10}H_{13}N$	147.16	$C_{10}H_{13}N$
20	—— α naphthylamine, 5:6:7:8	,,	147.16	,,
21	—— phenol, 2:1:2:3:4	$C_6H_5OH.H_4$	98.11	$C_6H_{10}O$
22	—— phthalic acid	$C_8H_4O_4.H_4$	170.12	$C_8H_{10}O_4$
23	—— quinoline, 1:2:3:4	$C_9H_7N.H_4$	133.14	$C_9H_{11}N$
24	———, iso., 1:2:3:4	,,	133.14	,,
25	— hydroxy anthrachrysones			
26	Oxypurpurin	$C_{14}H_4O_2(OH)_4$	272.13	$C_{14}H_8O_6$
27	Anthrachrysone	,, ,, $.2H_2O$	308.16	,,
28	Rufiopin	,, ,,	272.13	,,
29	α-Oxy anthra-gallol	,, ,,	272.13	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
		s.s.	v.s.	45—46	254	1
		h.s.		51	246	2
1.734/10°	v.s. C$_6$H$_6$	v.s.s	s.	137—138	243—246	3
1.5825/0°				129—130		4
1.614/0°				147		5
1.438/0°				liq.	189.7	6
	i.	v.s.	v.s.	230	subl.	7
	i.	o.v.s.s.	i.	250		8
	i.		v.s.	252		9
0.764/20°				5	252.5	10
0.774/15°				- 12	127/15mm.	11
	v.s.	s.		49—50		12
					254	13
					250	14
				liq.	80—81	15
1.109/20°	s.s.			29	240—243	16
0.981/12.5°				liq.	206	17
	h.s.s	v.s.	v.s.	69	264/716mm.	18
	v.s.	s.	s		249.5/710mm.	19
1 063/16°	s.	s.	s.		275/712mm	20
	s.			liq.	166	21
	v.s.			120 in vac.		22
1 0627/15°	s.				251	23
					229—230	24
						25
	v.s.s	v.s.s.	s. acetic	> 290		26
	i.	s.	v.s.s	> 360		27
	h.s.s.	s.	s.s.	subl.	s.	28
	v.s.s.	s.	s.s.	> 360		29

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	β-Oxy anthra-gallol	$C_{14}H_4O_2(OH)_4$	272.13	$C_{14}H_8O_6$
2	Quinalizarin	$,,$ (OH) $,,$	272.13	$,,$
3	Tetra hydroxy benzene, 1:2:4:5	$C_6H_2(OH)_4$	142.08	$C_6H_6O_4$
4	—— benzoic acid	$C_6H(OH)_4COOH$	186.08	$C_7H_6O_6$
5	—— quinone, 2:3:5:6	$C_6O_2(OH)_4$	172.06	$C_6H_4O_6$
6	—— iodo pyrrole, 2:3:4:5	$C_4NH.I_4$	570.72	C_4HNI_4
7	—— methyl ammonium hydroxide	$(CH_3)_4N.OH$	91.13	$C_4H_{13}ON$
8	—— benzene, 1:2:3:4, prehnitol	$C_6H_2(CH_3)_4$	134.16	$C_{10}H_{14}$
9	———, 1:2:3:5, β iso-durol	$,,$	134.16	$,,$
10	———, 1:2:4:5, durol	$,,$	134.16	$,,$
11	—— diamino benz-hydrol	$HO.CH[C_6H_4.N:(CH_3)_2]_2$	270.28	$C_{17}H_{22}ON_2$
12	——— benzophenone	$CO[C_6H_4.N:(CH_3)_2]_2$	268.27	$C_{17}H_{20}ON_2$
13	——— diphenyl-amine, 4:4'	$NH[C_6H_4.N:(CH_3)_2]_2$	255.28	$C_{16}H_{21}N_3$
14	——— triphenyl methane	$C_6H_5.CH[C_6H_4.N:(CH_3)_2]_2$	330.35	$C_{23}H_{26}N_2$
15	— methylene diamine	$NH_2.(CH_2)_4.NH_2$	88.14	$C_4H_{12}N_2$
16	— methyl succinic acid	$C_2(CH_3)_4(COOH)_2$	174.15	$C_8H_{14}O_4$
17	— nitro diphenol, 3:5:3':5':4:4'	$[C_6H_2(NO_2)_2OH]_2$	366.15	$C_{12}H_6O_{10}N_4$
18	—— diphenyl-methane, 2:4:2':4'	$CH_2[C_6H_3(NO_2)_2]_2$	348.17	$C_{13}H_8O_8N_4$
19	—— methane	$C(NO_2)_4$	196.05	CO_8N_4
20	—— naphthalene, α	$C_{10}H_4(NO_2)_4$	308.12	$C_{10}H_4O_8N_4$
21	———, β	$,,$ $,,$	308.12	$,,$
22	— phenyl ethane, α α β β	$(C_6H_5)_2:CH.CH:(C_6H_5)_2$	334.31	$C_{26}H_{22}$
23	—— ethylene	$(C_6H_5)_2:C:C:(C_6H_5)_2$	332.29	$C_{26}H_{20}$
24	Tetrazole	$\begin{array}{c} CH:N \\ | \quad \rangle NH \\ N:N \end{array}$	70.06	CH_2N_4
25	Tetrolic acid	$C_3H_3.COOH$	84.05	$C_4H_4O_2$

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	s.s.	s.	s.s.	> 380		1
	v.s.s.	s.s.	i.	> 275	subl.	2
	v.s.	v.s.	s.	215—220		3
				118		4
	h.s.	v.s.	s.s.			5
	i., s. C_6H_6	s.	v.s.	d. 140—150		6
	v.s.			d.		7
0.8816/9°				–	204	8
				liq.	195	9
	s. C_6H_6	s.	s.	79—80	189—191	10
		s.	s.	96		11
		s.	s.	174	>360	12
		s.	s. CS_2	119		13
	i.	s.	s.	102		14
	s.			23—24	158—160	15
	1 : 45	s.	v.s.	190—192	subl.	16
	i.	s.		225		17
		i.	i.	172		18
	i.	s.	s.	13	126 d.	19
	c.s.s.	s. $CHCl_3$	i.	259	expl.	20
		s.		200	expl.	21
1.18?	h.s. C_6H_6	s.s., s. $CHCl_3$	s. acetic.	209—211	358—362	22
	s. C_6H_6	s.s.	s.s.	227	415—425	23
		s.				
	s.	s.	s.s.	156	subl.	24
	v.s.	v.s.s.	s.	76—77	203	25

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Thiacetamide	$CH_3.CS.NH_2$	75.12	C_2H_5NS
2	Thiacetanilide	$CH_3.CS.NH.C_6H_5$	151.18	C_8H_9NS
3	Thiacetic acid	$CH_3.CO.SH$	76.10	C_2H_4OS
4	Thialdin	$C_6H_{13}NS_2$	163.26	$C_6H_{13}NS_2$
5	Thianthrene	$C_6H_4:S_2:C_6H_4$	216.24	$C_{12}H_8S_2$
6	Thiazole	C_3H_3NS	85.11	C_3H_3NS
7	Thio acetaldehyde	$(CH_3.CHS)_3$	180.31	$C_6H_{12}S_3$
8	— aniline	$(C_6H_4.NH_2)_2:S$	216.24	$C_{12}H_{12}N_2S$
9	— benzaldehyde, α	$C_6H_5.CHS$	122.14	C_7H_6S
10	— —, β	,,	122.14	,,
11	— benzoic acid	$C_6H_5.CO.SH.\frac{1}{2}H_2O$	147.15	C_7H_6OS
12	— carbamic acid	$CS(NH_2)SH$	93.16	CH_3NS_2
13	— carbamate, ethyl	$CS(NH_2)SC_2H_5$	121.20	$C_3H_7NS_2$
14	— carbanilide	$CS(NH.C_6H_5)_2$	228.24	$C_{13}H_{12}N_2S$
15	— cresol, o	$CH_3.C_6H_4.SH$	124.16	C_7H_8S
16	— —, m	,, ,,	124.16	,,
17	— —, p	,, ,,	124.16	,,
18	— cyanic acid	$NC.S.H$	59.08	$CHNS$
19	— cyanate, ethyl	$NC.S.C_2H_5$	87.13	C_3H_5NS
20	— —, methyl	$NC.S.CH_3$	73.10	C_2H_3NS
21	— cyanuric acid	$(C.NSH)_3$	177.25	$C_3H_3N_3S_3$
22	— diphenyl amine, 2:2'	$S(C_6H_4)_2:NH$	199.20	$C_{12}H_9NS$
23	— glycollic acid	$HS.CH_2.COOH$	92.10	$C_2H_4O_2S$
24	— hydroquinone	$C_6H_4(SH)_2$	142.20	$C_6H_6S_2$
25	— naphthen	$C_8H_4\genfrac{}{}{0pt}{}{/CH:CH}{\backslash S}$	134.15	C_8H_6S
26	— oxamide	$(CS.NH_2)_2$	120.18	$C_2H_4N_2S_2$
27	— oxaminate, ethyl	$NH_2.CS.COOC_2H_5$	133.14	$C_4H_7O_2NS$
28	— phenol, see	Phenyl mercaptan		
29	— phosgene	$CS:Cl_2$	114.99	$CSCl_2$
30	— resorcinol	$C_6H_4(SH)_2$	142.20	$C_6H_6S_2$
31	— tolene	$C_4H_3.CH_3.S$	98.13	C_5H_6S
32	— urea	$CS(NH_2)_2$	76.12	CH_4N_2S
33	— urethane	$NH_2.CO.S.C_2H_5$	105.14	C_3H_7ONS
34	Thionine	$C_{12}H_9N_3S$	227.22	$C_{12}H_9N_3S$
35	Thiophen	$\genfrac{}{}{0pt}{}{CH:CH}{CH:CH}\Big\rangle S$	84.11	C_4H_4S

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	v.s.		s.	108.5		1
	i.	s.	s. NaOH	75	d.	2
1.074/10°	s.s.	s.	s.	93	d.	3
1.191	s.s.	1 : 400	v.s.	43	d.	4
	i.	s.	s.	159	364—366	5
1.1998/17°	i.	s.	liq.	117		6
	i.	s.	i.	45—46	205	7
	h.s.	i.	s.	105		8
	i.	s.s.	s. C_6H_6	160	d.	9
		m.	s. acetic	225		10
	i.	s.	m.	24		11
	s.	v.s.	s.			12
	i.	s.	v.s.	42		13
1.3025/4°	v.s.s.		s.	153		14
	i.	s.		15	193	15
1.0625/0°				liq.		16
	i.	s.		43	190.2—191.7	17
	m.	m	s.	5	d. 200	18
⎧ 1.033/0° ⎨ 1.0126/9° ⎩	i.		m.	liq.	132—133 /753mm.	19
1.0693/23.8°		v.s.s.		liq.	133	20
	h.v.s.s.	s.s.	v.s.s.			21
			v.s.	180—181	371	22
	m.	m.	m.	− 16.5	107—108/15mm	23
				98		24
			s.	30—31	220—221	25
		s.	s.	d.		26
	h.s.	v.s.	v.s.	63		27
						28
1.5085/15°	v.s.s.				71—74	29
				27	243	30
1.0194				13	114/738mm.	31
1.42	1 : 11	v.s.s.	v.s.s.	180		32
	h.s.	s.	s.	108	subl.	33
	v.s.s.	s.s.				34
1.0705/15°	i.	s.	s.H_2SO_4	− 37.1	84	35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Thiophen alcohol	$C_4H_3S.CH_2OH$	114.13	C_5H_6OS
2	— aldehyde	$C_4H_3S.CHO$	112.12	C_5H_4OS
3	— carboxylic acid, 2	$C_4H_3S.COOH$	128.12	$C_5H_4O_2S$
4	— —, 3	,,	128.12	,,
5	Thujone	$C_{10}H_{18}O$	154.19	$C_{10}H_{18}O$
6	Thymene	$C_{10}H_{16}$	136.18	$C_{10}H_{16}$
7	Thymo hydroquinone	$C_{10}H_{18}O_2$	166.16	$C_{10}H_{14}O_2$
8	Thymol, 1 : 3 : 2	$C_6H_3(CH_3)(C_3H_7)OH$	150.16	$C_{10}H_{14}O$
9	—, iso., 3 : 2 : 1	,, ,,	150.16	,,
10	Thymoquinone	$C_{10}H_{12}O_2$	164.15	$C_{10}H_{12}O_2$
11	Thymotic acid	$C_6H_2(CH_3)(C_3H_7)(OH)$ COOH	194.17	$C_{11}H_{14}O_3$
12	— anhydride	$C_6H_2(CH_3)(C_3H_7)CO.O$	176.15	$C_{11}H_{12}O_2$
13	Tiglic acid	$C_5H_8O_2$	100.09	$C_5H_8O_2$
14	Tin diethyl	$Sn(C_2H_5)_2$	176.80	$C_4H_{10}Sn$
15	— tetraethyl	$Sn(C_2H_5)_4$	234.90	$C_8H_{20}Sn$
16	— tetramethyl	$Sn(CH_3)_4$	178.81	$C_4H_{12}Sn$
17	— triethyl	$Sn(C_2H_5)_3$	205.85	$C_6H_{15}Sn$
18	Tolane	$C_6H_5.C : C.C_6H_5$	178.15	$C_{14}H_{10}$
19	Tolidine, 3 : 3′ : 4 : 4′	$(CH_3.C_6H_3NH_2)_2$	212.22	$C_{14}H_{16}N_2$
20	—, 2 : 2′ : 4 : 4′	,, ,,	212.22	,,
21	—, 1 : 1′ : 4 : 4″	,, ,,	212.22	,,
22	Toluene	$C_6H_5.CH_3$	92.10	C_7H_8
23	— sulphamide, o	$CH_3.C_6H_4.SO_2.NH_2$	171.18	$C_7H_9O_2NS$
24	— —, m	,, ,,	171.18	,,
25	— —, p	,, ,,	171.18	,,
26	— sulphochloride, o	$CH_3.C_6H_4.SO_2Cl$	190.61	$C_7H_7O_2SCl$
27	— —, m	,, ,,	190.61	,,
28	— —, p	,, ,,	190.61	,,
29	Toluic acid, o	$CH_3.C_6H_4.COOH$	136.10	$C_8H_8O_2$
30	— —, m	,, ..	136.10	,,
31	— —, p	,, ,,	136.10	,,
32	Toluidine, o	$CH_3.C_6H_4.NH_2$	107.12	C_7H_9N
33	—, m	,, ,,	107.12	,,
34	—, p	,, ,,	107.12	,,
35	Toluhydroquinone,	see Dihydroxy toluene		

Density H₂O=1.	Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
				liq.	207	1
1.215/21°					197—198	2
	h.v.s.	v.s.	v.s.	126.5	260	3
	s.			136		4
0.9126/20°		s.	s.		210—212	5
				liq.	160—165	6
	h.s.	s.	s.	139.5	290	7
0.9941/0°	1 : 1200	s.	s.	50	232	8
				44	228—230	9
	v.s.s.	s.	s.	45.5	232	10
	h.s.s.	s.	s.	127	sub.	11
				174		12
	h.v.s.	s.	s.	64.5	198.5	13
1.654	i.	s.		liq.	d.	14
1.187/23°	i.			liq.	181/758mm.	15
1.3138/0°	i.			liq.	78	16
1.4115/0°	i.	i.		liq.	d. 270	17
		s.	s.	60		18
	s.s.	s.	s.	128		19
	h.s.	s.	s.	108—109		20
	s.s.	s.	s.	128—129		21
0.8708/13°	i.	s.s	s.	– 93.2	110.7	22
	1 :958/9°	1 :28/5°		153—154		23
	1 :376.7/14°	1 :5.74/14°		108		24
	1 :515/9°	1 :13.5/5°		135—137		25
				F.Pt. 10.0	126/10mm.	26
				F.Pt. 11.7		27
	d.			65—66.5	145—146/15mm.	28
1.0621/115°	0.12 : 100/25°	v.s.		103.5—104	259	29
1.0543/112°	0.1 : 100/25°	v.s.	v.s.	111—113	263	30
	0.035 : 100/25°	v.s.	v.s.	180	274—275	31
0.9986/20°				liq.	197.7	32
0.9986/20°			s.	liq.	203.3	33
0.9538/59.1°	s.s.	s.		45	200.4	34
						35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Toluquinone, 2 : 1 : 4	$CH_3.C_6H_3:O_2$	122.08	$C_7H_6O_2$
2	Toluyl aldehyde, o	$CH_3.C_6H_4.CHO$	120.10	C_8H_8O
3	— —, m	,, ,,	120.10	,,
4	— —, p	,, ,,	120.10	,,
5	— benzoic acid, 3 : 3′	$CH_3.C_6H_4.CO.C_6H_4.COOH$	240.17	$C_{15}H_{12}O_3$
6	— — —, 4 : 2′	,, ,, .$2H_2O$	276.20	,,
7	Toluylene diamine, 1 : 2 : 3	$CH_3.C_6H_3:(NH_2)_2$	122.14	$C_7H_{10}N_2$
8	— —, 1 : 2 : 4	,, ,,	122.14	,,
9	— —, 1 : 2 : 5	,, ,,	122.14	,,
10	— —, 1 : 2 : 6	,, ,,	122.14	,,
11	Tolyl alcohol, o	$CH_3.C_6H_4.CH_2OH$	122.12	$C_8H_{10}O$
12	— —, m	,, ,,	122.12	,,
13	— —, p	,, ,,	122.12	,,
14	— chloride, o	$CH_3.C_6H_4.CH_2Cl$	140.57	C_8H_9Cl
15	— —, m	,, ,,	140.57	,,
16	— —, p	,, ,,	140.57	,,
17	— diphenyl methane, m	$(C_6H_5)_2:CH.C_6H_4.CH_3$	258.24	$C_{20}H_{18}$
18	— — —, p	,,	258.24	,,
19	— hydrazine, o	$CH_3.C_6H_4.NH.NH_2$	122.14	$C_7H_{10}N_2$
20	— —, m	,, ,,	122.14	,,
21	—, p	,, ,,	122.14	,,
22	— phenyl ketone, o	$C_6H_5.CO.C_6H_4.CH_3$	196.17	$C_{14}H_{12}O$
23	— — —, p	,, ,,	196.17	,,
24	Tri acetamide	$N(C_2H_3O)_3$	143.11	$C_6H_9O_3N$
25	— acetin	$C_3H_5(O.CO.CH_3)_3$	218.16	$C_9H_{14}O_6$
26	— acetone amine	$C_9H_{17}.NO.H_2O$	173.21	$C_9H_{19}ON$
27	— amino azo benzene, 2 : 4 : 3′	$NH_2.C_6H_4.N_2.C_6H_3:(NH_2)_2$	227.21	$C_{12}H_{13}N_5$
28	— — benzene, 1 : 2 : 3	$C_6H_3(NH_2)_3$	123.13	$C_6H_9N_3$
29	— — —, 1 : 2 : 4	,,	123.13	,,
30	— — benzoic acid, 3 : 4 : 5 : 1	$(NH_2)_3C_6H_2.COOH.1\frac{1}{2}H_2O$	194.17	$C_7H_9O_2N_3$
31	— — — —, 2 : 3 : 5 : 1	,,	167.14	,,
32	— — phenol	$(NH_2)_3C_6H_2.OH$	139.13	$C_6H_9ON_3$
33	— amyl amine	$(C_5H_{11})_3N$	227.35	$C_{15}H_{33}N$
34	— azole, 1 : 2 : 4	$\begin{array}{c}CH:N\\ \mid\qquad\quad\diagdown\\ \qquad\qquad NH\\ N=CH\diagup\end{array}$	69.06	$C_2H_3N_3$

Density H$_2$O=1.	Solubility in Water	Alcohol	Ether	M.P. °C.	B.P. °C.	
	h.s.	v.s.	v.s.	67	subl.	1
1.024/22°				liq.	200	2
1.072/12°				liq.	199	3
				liq.	204	4
	h.s.s.	s.	s.	228	d.	5
	h.v.s.s.	v.s.	v.s.	140	d.	6
			s.	61—62	255	7
				99	280	8
	s.	s.	s., s. C$_6$H$_6$	64	273—274	9
			s.		103.5—105	10
1.023/40°	s.s.	s.	s.	31	223/750mm.	11
0.9157/17°	s			liq.	217	12
	h.s.s.	s.	s.	60	217—221	13
					197—199	14
1.064/20°					195—196	15
					192	16
		s.	s.	62	353—354.7 /774mm	17
	i.	h.s.	s.	71	>360	18
	s. CHCl$_3$	s.	s.	56		19
				liq.	240—244	20
	s. C$_6$H$_6$	s.	s.	61	240—244	21
					315—316	22
	s. C$_6$H$_6$	s.s.	s.	59—60	326.5	23
			s.	78—79		24
1.55	i.	m.	m.	liq.	258—259	25
	s.		s.	58, an. 39.6		26
	h.s.s.	v.s.	v.s., s. C$_6$H$_6$	144		27
	v.s.	v.s.	v.s.	103	330	28
	v.s.	v.s.	s.s. CHCl$_3$	< 100	340	29
	h.s.	i.	i.			30
	h.s.	h.v.s.s.	i.			31
						32
				liq.	257	33
	s.	s.	s.s.	120—121	260	34

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Tri benzoyl methane	$CH(CO.C_6H_5)_3$	328.24	$C_{22}H_{16}O_3$
2	- benzyl amine	$N(C_6H_5.CH_2)_3$	287.28	$C_{21}H_{21}N$
3	— brom acetic acid	$CBr_3.COOH$	296.78	$C_2HO_2Br_3$
4	—— aniline, 2:4:6	$C_6H_2(Br_3)NH_2$	329.83	$C_6H_4NBr_3$
5	—— benzene, 1:2:3	$C_6H_3Br_3$	314.81	$C_6H_3Br_3$
6	———, 1:3:4	,,	314.81	,,
7	———, 1:3:5	,,	314.81	,,
8	—— hydrin	$CH_2Br.CHBr.CH_2Br$	280.82	$C_3H_5Br_3$
9	—— phenol, 2:4:6	$C_6H_2OH(Br_3)$	330.81	$C_6H_3OBr_3$
10	—— resorcinol, 2:4 :	$C_6H(OH)_2(Br)_3$	346.81	$C_6H_4O_2Br_3$
11	— butyl amine	$(C_4H_9)_3N$	185.29	$C_{12}H_{27}N$
12	— carballylic acid	$C_3H_5(COOH)_3$	176.09	$C_6H_8O_6$
13	— chlor acetal, 1	$CHCl_2.CCl(OC_2H_5)_2$	221.50	$C_6H_{11}O_2Cl_3$
14	———, 2	$CCl_3.CH(OC_2H_5)_2$	221.50	,,
15	—— acetamide	$CCl_3.CO.NH_2$	162.42	$C_2H_2ONCl_3$
16	—— acetic acid	$CCl_3.COOH$	163.40	$C_2HO_2Cl_3$
17	—— acetate, ethyl	$CCl_3.COO.C_2H_5$	191.44	$C_4H_5O_2Cl_3$
18	—— aniline, 1:2:3:4	$NH_2.C_6H_2Cl_3$	196.45	$C_6H_4NCl_3$
19	———, 1:2:4:5	,, ,,	196.45	,,
20	———, 1:2:4:6	,, ,,	196.45	,,
21	—— benzene, 1:2:3	$C_6H_3Cl_3$	181.43	$C_6H_3Cl_3$
22	———, 1:2:4	,,	181.43	,,
23	———, 1:3:5	,,	181.43	,,
24	—— benzoic acid, 1:2:4:5	$HOOC.C_6H_2Cl_3$	225.44	$C_7H_3O_2Cl_3$
25	————, 1:2:3:4	,, ,,	225.44	,,
26	————, 1:3:4:5	,, ,,	225.44	,,
27	—— ethane, α α β	$CH_2Cl.CHCl_2$	133.41	$C_2H_3Cl_3$
28	———, methyl chloroform	$CH_3.CCl_3$	133.41	,,
29	—— ethylene	C_2HCl_3	131.40	C_2HCl_3
30	—— hydrin	$CH_2Cl.CHCl.CH_2Cl$	147.44	$C_3H_5Cl_3$
31	—— hydroquinone	$C_6HCl_3(OH)_2$ (2:3:5)	213.43	$C_6H_3O_2Cl_3$
32	—— lactic acid	$CCl_3.CHOH.COOH$	193.42	$C_3H_3O_3Cl_3$
33	—— phenol, 1:2:4:6	$OH.C_6H_2Cl_3$	197.43	$C_6H_3OCl_3$
34	———, 1:2:3:5	,,	197.43	,,
35	—— quinone, 2:3:5	$C_6HO_2(Cl_3)$	211.42	$C_6HO_2Cl_3$

Density H$_2$O=1.	Water.	Solubility in—Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	s. CS$_2$	v.s.s.	v.s.s.	223—226	subl.	1
	v.s.s.	h.s.	s.	91		2
	s.	s.		135	d. 245	3
				122	300	4
		s.		87.4		5
		s.s.		44	275—276	6
		h.s.s.		119.6	278	7
2.436/23°				16	219—221	8
	v.s.s.	v.s		94	subl.	9
	h.s.s.	s.		112		10
0.7782/20°				171	211—215 /740mm	11
	s.	s.	s.s.	165		12
	s.	s.		83	230	13
1.288	v.s.s.	m.	m.	liq.	199—205	14
	h.s.s.	s.	s.	141	238—239	15
1.63/61°	v.s.	s.	o.	57	196—197	16
1.369/15°	i.			liq.	164	17
				67.5	292	18
				95—96	270	19
		s.	s.	77	262	20
		s.s.		53—54	218—219	21
⎰ 1.574/10° solid. ⎱ 1.466/10° liq				16	213	22
				63.4	208.5	23
	h.s.	s.		163	subl.	24
	v.s.			129		25
	v.s.s.	s.	s., s. C$_6$H$_6$	203	subl.	26
1.4406/25.5°				114		27
1.3249/26°					74	28
				88		29
1.417/15°				liq.	154—156	30
	h.s.	s.	s.	134		31
	s.	s.	s.	115—118		32
	v.s.s.	v.s.	v.s.	68	243.5—244.5	33
	h.s.	s.	s.	53—54	252—253	34
	v.s.s.	h.s.	s.	165—166		35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Tri decane	$C_{13}H_{28}$	184.29	$C_{13}H_{28}$
2	— decylene	$C_{13}H_{26}$	182.27	$C_{13}H_{26}$
3	— ethyl amine	$(C_2H_5)_3N$	101.16	$C_6H_{15}N$
4	— — arsine	$(C_2H_5)_3As$	162.11	$C_6H_{15}As$
5	— — benzene, 1:3:5	$C_6H_3(C_2H_5)_3$	162.20	$C_{12}H_{18}$
6	— — phosphine	$(C_2H_5)_3P$	118.19	$C_6H_{15}P$
7	— — — oxide	$(C_2H_5)_3PO$	134.19	$C_6H_{15}OP$
8	— — — sulphide	$(C_2H_5)_3PS$	150.25	$C_6H_{15}SP$
9	— — silicol	$(C_2H_5)_3Si.OH$	132.3	$C_6H_{16}OSi$
10	— — — ester	$(C_2H_5)_3Si.OC_2H_5$	160.3	$C_8H_{20}OSi$
11	— — — oxide	$Si_2(C_2H_5)_6O$	246.5	$C_{12}H_{30}OSi_2$
12	— ethylene diamine	$(C_2H_4)_3N_2$	112.15	$C_6H_{12}N_2$
13	— hydroxy benzene,	1:2:4, see Hydroxy hydroquinone		
14	— — anthraquinone			
15	1. Anthragallol	$C_{14}H_5O_2(OH)_3$	256.13	$C_{14}H_8O_5$
16	2. Purpurin	,, ,, $.H_2O$	274.15	,,
17	3. Anthrapurprin	,, ,,	256.13	,,
18	4. Flavopurprin	,, ,,	256.13	,,
19	— — benzoic acid, 2:3:4:1	$C_6H_2(OH)_3COOH$ ($\frac{1}{3}H_2O$)	170.08	$C_7H_6O_5$
20	— — benzo phenone	$C_{13}H_{10}O_4$	230.15	$C_{13}H_{10}O_4$
21	— — methylene, a	$C_3H_6O_3$	90.06	$C_3H_6O_3$
22	— — pyridine, 2:4:6	$C_5H_2N(OH)_3$	127.08	$C_5H_7O_3N$
23	— iodo benzene, 1:2:3	$C_6H_3I_3$	455.81	$C_6H_3I_3$
24	— — —, 1:2:4	,,	455.81	,,
25	— — —, 1:3:5	$C_6H_3I_3$	455.81	$C_6H_3I_3$
26	— mellitic acid, 1:2:4	$C_6H_3(COOH)_3$	210.09	$C_9H_6O_6$
27	— mesic acid, 1:4:5	,,	210.09	,,
28	— methyl acetic acid	$(CH_3)_3C.COOH$	102.10	$C_5H_{10}O_2$
29	— — amine	$(CH_3)_3N$	59.10	C_3H_9N
30	— — arsine	$(CH_3)_3As$	120.05	C_3H_9As
31	— — benzene, 1:2:3	$C_6H_3(CH_3)_3$	120.14	C_9H_{12}
32	— — benzoic acid, 1:3:5:2	$(CH_3)_3C_6H_2.COOH$	165.15	$C_{10}H_{12}O_2$
33	— — cyclo hexane, see	Hexa hydro cumene		
34	— — ethylene	$(CH_3)_2:C:CH.CH_3$	70.10	C_5H_{10}
35	— — phosphine	$(CH_3)_3P$	76.13	C_5H_9P
36	— — quinoline, 2:3:4	$C_{12}H_{13}N$	171.17	$C_{12}H_{13}N$
37	— — —, 2:5:7	,,	171.17	,,
38	— — —, 2:3:6	,,	171.17	,,

Density $H_2O=1$.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
0.7608/15°				− 6.2	234	1
0.8445/0°					232.7	2
0.7331/15°	s.s.	s.		liq	89	3
1.151/17°	i.			liq.	140/736mm	4
						5
9.812/15°	i.	s.	s.	liq.	127.5/744	6
		m.	m.	52.9	242.9	7
				95	subl. 120 —145	8
0.8709/0°	i.			liq.	154	9
0.8403/0°				liq.	153	10
0.859/0°				liq.	231	11
				liq.	210	12
						13
						14
	v.s.s.	s.	s.	310	subl. 290	15
	s.s.	s.	s., s. C_6H_6	256	subl. 150	16
	h.s.s.	h.s.	s.s.	369	462	17
	h.s.s.	s.	s.s.	> 330	459	18
1.694/4°	h.s.	s.	v.s.	an. 110		19
		h.s.	s. C_6H_6	133—134		20
	s.	s.	i.	152	subl	21
	s.s.	i.	i.	220—230 d.		22
		s.		116	subl.	23
				91.4		24
				182—184		25
	v.s.		v.s.	215—217		26
	h.s.	v.s.	s.	345—350	subl.	27
0.905/50°	1 : 45/20°			38	162—164	28
0.673/0°	v.s.	v.s.			3.2—3.8	29
	s.s.			70		30
0.8694/10°					175—175.5	31
	h.s.s.	v.s.	v.s.	152		32
						33
0.6783/0°					36.4—37.2	34
> H_2O	i.			liq	40—42	35
				65	285	36
	s.	v.s.	s.s.	43	285—287	37
		s.	s.	86—87	285	38

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Tri methyl quinoline, 2:6:8	$C_{12}H_{13}N$	171.17	$C_{12}H_{13}N$
2 ———, 2:4:6	,,	171.17	,,
3 — methylene bromide	$CH_2Br.CH_2.CH_2Br$	201.90	$C_3H_6Br_2$
4 —— diamine	$NH_2.(CH_2)_3.NH_2$	74.12	$C_3H_{10}N_2$
5 —— dicarboxylic acid	$\begin{array}{c}CH_2\\ \\CH_2\end{array}\!\!>\!O:(COOH)_2$	130.07	$C_5H_6O_4$
6 —— glycol	$CH_2OH.CH_2.CH_2OH$	76.08	$C_3H_8O_2$
7 —— sulphide	$C_3H_6S_3$	138.24	$C_3H_6S_3$
8 — nitro aceto-nitrile	$C(NO_2)_3.CN$	86.10	$C_2H_6N_4$
9 —— aniline, see	Picramide		
10 —— benzene, 1:3:5	$C_6H_3(NO_2)_3$	213.08	$C_6H_3O_6N_3$
11 —— naphthalene, 1:3:5	$C_{10}H_5(NO_2)_3$	263.12	$C_{10}H_5O_6N_3$
12 ———, 1:3:8	,, ,,	263.12	,,
13 ———, 1:4:5	,, ,,	263.12	,,
14 —— orcinol	$C_6(NO_2)_3(CH_3)(OH)_2$	259.10	$C_7H_6O_8N_3$
15 —— phenol, 1:2:4:6, picric acid	$OH.C_6H_2(NO_2)_3$	229.08	$C_6H_3O_7N_3$
16 ———, 1:3:4:6	,, ,,	229.08	,,
17 ———, 1:2:3:6	,, ,,	229.08	,,
18 —— resorcinol	$C_6H(NO_2)_3(OH)_2$	245.08	$C_6H_3O_8N_3$
19 —— toluene, 1:2:4:6	$CH_3.C_6H_2(NO_2)_3$	227.10	$C_7H_5O_6N_3$
20 ———, 1:3:4:6	,, ,,	227.10	,,
21 ———, β	,, ,,	227.10	,,
22 —— xylene, 2:4:6:1:3	$C_6H(NO_2)_3(CH_3)_2$	241.13	$C_8H_7O_6N_3$
23 ———, 2:3:5:1:4	,, ,,	241.13	,,
24 — phenyl acetic acid	$(C_6H_5):C.COOH$	288.23	$C_{20}H_{16}O_2$
25 —— amine	$(C_6H_5)_3N$	245.22	$C_{18}H_{15}N$
26 —— benzene, 1:3:5	$C_6H_3(C_6H_5)_3$	306.26	$C_{24}H_{18}$
27 —— carbinol	$(C_6H_5)_3COH$	260.22	$C_{19}H_{16}O$
28 —— dihydro glyoxaline	$\begin{array}{c}C_6H_5.CH.NH\\ \quad\mid\qquad\;\;>C_6H_5\\C_6H_5.CH.N\end{array}$	298.27	$C_{21}H_{18}N_2$
29 —— guanidine, α	$C_6H_5.N:C:(NH.C_6H_5)_2$	287.17	$C_{19}H_{17}N_3$
30 ———, β	,, ,,	287.17	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
	t.	v.s.	s.	45—46	266—267 /780mm.	1
	s			63—64	277—278	2
1.973/17°				liq.	160—163 /719mm.	3
		m.	m.		135—136 /738mm.	4
	v.s		s.	139		5
1.0526/18°	m.			liq.	216	6
	h.s.s.	s.s.	s.s.	216	subl.	7
	d.	d.	s.	41.5		8
						9
	h.s.	h.s.	s., s. C_6H_6	122	d.	10
	s. acetic.	s.	s. $CHCl_3$	122		11
	v.s.s. $CHCl_3$	v.s.s.	v.s.s.	218		12
	s.s. C_6H_6	s.s.	s.s.	154		13
	h.s.	s. C_6H_6	s.s.	163.5		14
1.767/19°	1.525 : 100/30°	s.	s.	122.5	subl. expl.	15
	h.s.	v.s.	v.s.	96		16
	h.s.	v.s.	v.s.	117—118		17
	s.s.	s.	s.	175.5	subl.	18
		h.s.		80.8—80.85		19
	s. acetone.	v.s.s.	s., s. C_6H_6	104		20
	s. acetone.	hs., s. C_6H_6	s., s. CS_2	**112**		21
		h.s.s.		182		22
		h.v.s.		139—140		23
		s.s.		267 d.		24
		s.s.	s. C_6H_6	127	347—348	25
1.206	s. C_6H_6	s.s. (50%)	s.s.	170	>300	26
		s.	s.	162.5	>360	27
		s.	s.	113, iso. 198		28
	h.v.s.s.	s.		143	d.	29
	v.s.s.	s.	s.	311		30

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Tri phenyl methane	$(C_6H_5)_3CH$	244.22	$C_{19}H_{16}$
2	— — carboxylic acid	$(C_6H_5)_2:CH.C_6H_4.COOH$	288.22	$C_{20}H_{16}O_2$
3	— — oxazole	$C_6H_5.C\begin{smallmatrix}O.C.C_6H_5\\ \|\|\\ N.C.C_6H_5\end{smallmatrix}$	297.24	$C_{21}H_{15}ON$
4	— quinonyl	$C_6H_{16}O_{14}$	312.16	$C_6H_{16}O_{14}$
5	— thiocarbonic acid	$CS(SH)_2$	110.20	CH_2S_3
6	Tropic acid, i	$C_6H_5.CH(COOH).CH_2OH$	166.13	$C_9H_{10}O_3$
7	— —, d	,, ,,	166.13	,,
8	— —, l	,, ,,	166.13	,,
9	Tropidine	$C_8H_{13}N$	123.15	$C_8H_{13}N$
10	Tryptophane	$C_6H_4.C.CH_2.CH.NH_2$ $\quad\quad\|\quad\quad\|\|$ $\quad NH—CH \quad COOH$	204.17	$C_{11}H_{12}O_2N_2$
11	Tyrosine, θ	$OH.C_6H_4.C_2H_3(NH_2)COOH$	181.14	$C_9H_{11}O_3N$
12	—, m	,, ,,	181.14	,,
13	—, d	,, ,,	181.14	,,
14	—, l	,, ,,	181.14	,,
15	Umbellic acid	$C_9H_8O_4$	180.00	$C_9H_8O_4$
16	Umbelliferone	$C_9H_6O_3$	162.09	$C_9H_6O_3$
17	Undecane	$CH_3.(CH_2)_9.CH_3$	156.25	$C_{11}H_{24}$
18	Uramil	$CO\begin{smallmatrix}NH.CO\\ \\ NH.CO\end{smallmatrix}CH.NH_2$	143.09	$C_4H_5O_3N_3$
19	Urea	$CO:(NH_2)_2$	60.06	CH_4ON_2
20	Urethane	$CO(NH_2)OO_2H_5$	89.08	$C_3H_7O_2N$
21	Uric acid	$NH.CO$ $\quad\|\quad\|$ $CO\;C.NH$ $\quad\|\quad\|\|\quad CO$ $NH.C.NH$	168.10	$C_5H_4O_3N_4$
22	Urotropine, see	Hexamethylene tetramine		
23	Usnic acid, d	$C_{18}H_{16}O_7$	344.22	$C_{18}H_{16}O_7$
24	— —, l	,,	344.22	,,
25	Uvitic acid, 1 : 3 : 5	$CH_3.C_6H_3:(COOH)_2$	180.11	$C_9H_8O_4$
26	— —, iso.	,, ,,	180.11	,,
27	Uvitonic acid	$CH_3.C_5H_2N:(COOH)_2$	181.11	$C_8H_7O_4N$

Density $H_2O=1$.	Solubility in			M.P. °C.	B.P. °C.	
	Water.	Alcohol.	Ether.			
1.0166/95°	h.s. C_6H_6	h.s.	s.	94—95	358—359 /754mm.	1
	i.	s.	s.	162		2
		s.	s.	115		3
	h.s.	i.	i.	95 d.		4
	i.			liq.		5
	s.	s.	s.	117—118	d.	6
				127—128		7
				123		8
$\{$ 0.9467/19° $\{$ 0.9665/0°	c.s., h.s.s.	v.s.	v.s.	liq	162—163	9
	s.	i.	i.	289		10
1.456	h.s.	v.s.s	i.	249—250		11
				280—281		12
				310—314		13
				295 d.		14
	h.s.	s.	i.	d. 125		15
	h.s.	s.	s.s.	223—224	subl.	16
$\{$ 0.756/0° $\{$ 0.7448/15°				26.5	194	17
	h.s.s		s. NH_4OH			18
1.323	1 : 1	1 : 20	s.s.	132—133	d.	19
0.9862/21°	s.	s.	s.	49—50	184	20
1.855—1.893	v.s.s.	i.	i.	d.	d.	21
						22
	i.	s.s.	s.	195—196	d.	23
				197—198		24
	h.v.s.s.	s.	s.	274	ubl.	25
	h.s.	s.	s.	175		26
	v.s.s.	s. ac.	s. aniline	274 d.		27

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Valeraldehyde, **norm.**	$CH_3.(CH_2)_3.CHO$	86.11	$C_5H_{10}O$
2	—, *iso.*	$(CH_3)_2:CH.CH_2OHO$	86.11	,,
3	Valeramide	$C_4H_9.CO.NH_2$	101.12	$C_5H_{11}ON$
4	Valeric acid, i, norm.	$CH_3.(CH_2)_3.COOH$	102.10	$C_5H_{10}O_2$
5	— —, 2, Iso propyl acetic acid	$(CH_3)_2:CH.CH_2.COOH$	102.10	,,
6	— —, 3, Pivalic acid, see	Trimethyl acetic acid		
7	Valerate, iso, iso amyl	$C_4H_9.COO.C_5H_{11}$	172.21	$C_{10}H_{20}O_2$
8	—, —, ethyl	$C_4H_9.COO.C_2H_5$	130.15	$C_7H_{14}O_2$
9	—, methyl	$C_4H_9.COO.CH_3$	116.13	$C_6H_{12}O_2$
10	Valeric anhydride	$(C_4H_9.CO)_2:O$	186.19	$C_{10}H_{18}O_3$
11	Valerylene	$(CH_3)_2:C:C.CH_2$	68.09	C_5H_8
12	Vanillic acid	$C_6H_3(OCH_3)(OH)COOH$	168.10	$C_8H_8O_4$
13	— alcohol	$C_6H_3(OCH_3)(OH)CH_2OH$	154.12	$C_8H_{10}O_3$
14	Vanillin, 2 : 1 : 4	$C_6H_3(OCH_3)(OH)CHO$	152.10	$C_8H_8O_3$
15	Veratrol	$C_6H_4:(OCH_3)_2$	138.12	$C_8H_{10}O_2$
16	Vinyl amine	$C_2H_3.NH_2$	43.06	C_2H_5N
17	— bromide	$CH_2:CHBr$	106.95	C_2H_3Br
18	— chloride	$CH_2:CHCl$	62.49	C_2H_3Cl
19	— sulphide	$(C_2H_3)_2S$	86.13	C_4H_6S
20	Violuric acid	$CO\begin{array}{c}NH.CO\\ \diagdown\\NH.CO\end{array}C:NOH .H_2O$	175.09	$C_4H_3O_4N_3$
21	Xanthene	$C_6H_4\begin{array}{c}CH_2\\ \diagup \diagdown\\ O\end{array}C_6H_4$	182.15	$C_{13}H_{10}O$
22	Xanthogen amide	$CS(OC_2H_5)NH_2$	105.14	C_3H_7ONS
23	Xanthogenic acid	$CS(OC_2H_5)SH$	122.18	$C_3H_6OS_2$
24	Xanthogenate, ethyl	$CS(OC_2H_5)S.C_2H_5$	150.23	$C_5H_{10}OS_2$
25	Xanthone	$C_6H_4\begin{array}{c}CO\\ \diagup \diagdown\\ O\end{array}C_6H_4$	196.13	$C_{13}H_8O_2$
26	Xanthopurpurin, see	Dihydroxy anthraquinone		
27	Xylene, *o*	$(CH_3)_2:C_6H_4$	106.12	C_8H_{10}
28	—, *m*	,, ,,	106.12	,,
29	—, *p*	,, ,,	106.12	,,
30	— dihydro, 1 : 3 : 1 : 2	$(CH_3)_2:C_6H_4(H_2)$	108.14	C_8H_{12}
31	— —, 1 : 4 : 1 : 2	,, ,,	108.14	,,

Density H₂O=1.	Solubility in Water.	Solubility in Alcohol.	Solubility in Ether.	M.P. °C.	B.P. °C.	
0.8185/11.2°	s.s	s.		liq.	103.4	1
0.8041/15°	s.s.	s.	s.	liq.	92—93	2
	s	s.	s.	126—128	230—232	3
0.9415/20°	l : 27/16°			- 18 to —20	185	4
0.9298/20°	l : 24/20°			- 51	173.7	5
						6
0.8765/20°	s.s.	m.	m.	liq.	189—190 /757.4mm	7
0.9007/0°	i.	s.		liq.	144.6	8
0.9097/0°					127.3	9
0.9290/27°				liq.	205	10
0.7000/0°				liq.	55.5—56	11
	h.s.	s.		211	subl.	12
	h.s.	s.	s.	115		13
	h.s.	s.	s.	81	subl.	14
1.086/15°				22.7	205—207	15
					56	16
1.5167/14°				liq.	16/750mm.	17
				- 15		18
0.9125	s.s.	m.	m.		101	19
	h.s.	s.				20
	v.s.s.	s.	s.	105	300—301	21
	s.s.	s.	s.s.	38		22
>H₂O	i.			liq.	d. 24	23
1.085/19°		s.		liq.	200	24
	h.s.s.	h.s.	s.s.	173—174	349—350 /730mm.	25
						26
0.8633/20°	i.	v.s.	v.s.	- 27.1	144.6	27
0.8642/20°	i.	v.s.	v.s.	- 54.8	138.8—139.2	28
0.8612/20°	i.	v.s.	v.s.	13.2	137.8—138.1	29
			l.	liq.	131.5—133 /740mm.	30
					132.5—133.5	31

Q

Name.	Formula.	Formula Weight.	Empirical Formula.
1 Xylene, dihydro, 1:5:1:2	,, ,,	108.14	,,
2 ——, 3:5:1:2	,, ,,	108.14	,,
3 ——, 3:6:1:2	,, ,,	108.14	,,
4 ——, 4:5:1:2	,, ,,	108.14	,,
5 ——, 2:5:1:4	,, ,,	108.14	,,
6 —, tetrahydro, m, 1:2:3:4	C_8H_{14}	110.15	C_8H_{14}
7 — sulphonic acid, 1:2:4	$C_6H_3(CH_3)_2SO_3H$	186.18	$C_8H_{10}O_3S$
8 Xylenol, 1:2:3	$C_6H_3(CH_3)_2OH$	122.12	$C_8H_{10}O$
9 —, 1:2:4	,, ,,	122.12	$C_8H_{10}O$
10 —, 1:3:2	,, ,,	122.12	,,
11 —, 1:3:4	,, ,,	122.12	,,
12 —, 1:3:5	,, ,,	122.12	,,
13 —, 1:4:2	,, ,,	122.12	,,
14 Xylic acid, 1:3:4	$C_6H_3(CH_3)_2COOH$	150.13	$C_9H_{10}O_2$
15 ——, 1:2:4	,, ,,	150.13	,,
16 ——, 1:3:2	,, ,,	150.13	,,
17 Xylidic acid, 1:2:5	$C_6H_3(CH_3)(COOH)_2$	180.11	$C_9H_8O_4$
18 ——, 1:2:4	,, ,,	180.11	,,
19 ——, 1:2:3	,, ,,	180.11	,,
20 Xylidine, 1:2:3	$C_6H_3(CH_3)_2NH_2$	121.14	$C_8H_{11}N$
21 —, 1:2:4	,, ,,	121.14	,,
22 —, 1:3:4	,, ,,	121.14	,,
23 —, 1:3:5	,, ,,	121.14	,,
24 —, 1:4:2	$C_6H_3(CH_3)_2NH_2$	121.14	$C_8H_{11}N$
25 Xyloquinone, 2:3	$(CH_3)_2C_6H_2O_2$	136.10	$C_8H_8O_2$
26 —, 2:6	,, ,,	136.10	,,
27 —, 2:5	,, ,,	136.10	,,
28 Xylorcin, 1:3:4:6	$(CH_3)_2:C_6H_2:(OH)_2$	138.12	$C_8H_{10}O_2$
29 Xylose, d	$C_6H_5(OH)CHO$	150.11	$C_6H_{10}O_5$
30 Xylylene alcohol, o	$CH_2OH.C_6H_4.CH_2OH$	138.12	$C_8H_{10}O_2$
31 ——, m	,, ,,	138.12	,,
32 ——, p	,, ,,	138.12	,,
33 — cyanide, o	$CH_2CN.C_6H_4.CH_2CN$	156.13	$C_{10}H_8N_2$
34 ——, m	,, ,,	156.13	,,
35 ——, p	,, ,,	156.13	,,

Density H₂O=1.	Solubility in Water.	Alcohol.	Ether.	M.P. °C.	B.P. °C.	
					129—130 /745mm.	1
					132—134	2
					135—138	3
					135.5—136.5	4
					133—134 /720mm	5
0.814/0°					124—125	6
	s.			d.	19	7
	s.	s.		75	218	8
	s.	s.		55	225	9
	h.v.s.	s.		49	211—212	10
1.0362/0°	v.s.s.	m.	m.	26	211.5	11
0.9709/81°	s.	s.		64	219.5	12
0.98/8°	s.	s.		74.5	211.5	13
	h.s.s.	s.	s.	126—127	267/727mm.	14
	h.v.s.s.	v.s.		165—166		15
	s.			97—99	274.5	16
	h.s.s.	s.		280—283		17
	s.s.	h.v.s.		320—330	subl.	18
				144 d.		19
0.991/15°				liq.	223/739mm.	20
1.0755/17.5°	s.s.		s. ligroin.	49	226	21
0.9184/15°				liq.	212	22
0.9935/0°				liq.	220—221	23
0.98/15°				15.5	215/739mm.	24
	s.s.		s.	55	subl	25
				72—73		26
	h.s.s.	s.s.	s.	61	subl.	27
	s.	s.	s.	124—125	276—279	28
	v.s.			141.5—149		29
	s.	s.	s.	64.2—64.8		30
1.161/18°	v.s.	s.		46—47		31
	v.s.	v.s.	v.s.	112—113		32
		v.s.	v.s.	59—60		33
		s.	s.CHCl₃	28—29	305—310/300mm.	34
	h.s.s.	h.s.	s.CHCl₃	98		35

	Name.	Formula.	Formula Weight.	Empirical Formula.
1	Xylylene dichloride, o	$CH_2Cl.C_6H_4.CH_2Cl$	175.02	$C_8H_8Cl_2$
2	— —, m	,, ,,	175.02	,,
3	— —, p	,, ,,	175.02	,,
4	Zinc diethyl	$Zn(C_2H_5)_2$	123.47	$C_4H_{10}Zn$
5	— dimethyl	$Zn(CH_3)_2$	95.43	C_2H_6Zn

Density $H_2O=1$.	Solubility in			M.P. °C.	B.P. °C.	
	Water.	Alcohol.	Ether.			
$1.393/0°$		v.s.		54.6—54.8	239—241	1
$1.302/20°$				34.2	250—255	2
$1.417/0°$				98—99	240—250	3
$1.182/18°$	d.	d.	s.	– 28	118	4
$1.386/10.5°$	d.			– 40	46	5

QUALITATIVE ANALYSIS.
Dry-way Tests.

The Bunsen flame has three main parts:

The inner portion (G), in which no combustion occurs, and in which the gas mixture contains about 60 per cent. of air, may be used for cooling beads from the reducing flame, to avoid oxidation; the mantle of the flame, including D, in which combustion of the mixed gases occurs; and the luminous portion, containing F, which is present only if there is an insufficient supply of air.

The six portions of the flame used are:

A. *Base of flame.* Lowest temperature, for obtaining the flame coloration of the most volatile substance in a mixture of substances which colour the flame.

B. *Zone of fusion.* Highest temperature (about 1700° C.), for testing fusibility, volatility, etc.

C. *Lower oxidising flame.* For further oxidation of oxides dissolved in beads.

D. *Upper oxidising flame.* Best with draught holes completely open. For all oxidations unless they require a higher temperature.

E. *Lower reducing flame.* As this contains unused air, it is not so energetic as F, and serves especially for reductions on charcoal and of beads of fused salts, a small flame being used for the latter.

F. *Upper reducing flame.* Not visible when draught holes are quite open, but if made too large, soot is deposited. Contains carbon, but no free oxygen, and is therefore particularly suitable for reduction of metals to be identified as incrustations.
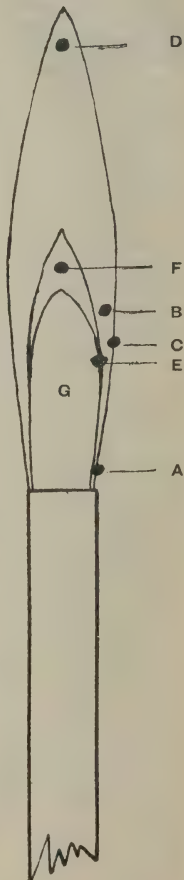
TEST 1.

A small amount of the substance is heated in a dry ignition tube.

The colour of the residue, and the nature of any gas evolved, is noted, and the behaviour of the residue and of the gas towards moistened litmus paper examined.

(a) *Character of Residue.*

Nitrates, carbonates, sulphates, etc., of many heavy metals, also certain metals, leave black or coloured residues of oxides on ignition.

Water vapour is formed, and condenses in the cooler portions of the test-tube : from moist substances, and in larger amounts at comparatively low temperatures from salts containing water of crystallisation, and at higher temperatures from the dehydration of hydroxides and the decomposition of certain ammonium salts. The behaviour of the condensed water towards litmus paper is examined :

Alkaline reaction indicates an ammonium salt.

Acid reaction indicates presence of a volatile acid, such as one of the halogen acids, sulphurous, sulphuric, nitric, or acetic acid.

Many *Organic compounds* carbonise on heating, giving a black residue.

Metallic chlorides (silver chloride, sodium chloride, etc.) are characterised by the comparative readiness with which they can be fused.

Substance	Original colour	Colour on heating
Lead monoxide	Yellowish brown	*Reddish brown (fuses into test-tube, forming bright yellow glass)
Mercuric oxide	Scarlet or yellow	*Black (on heating to a higher temperature gives oxygen and globules of mercury)
Bismuth oxide	Greenish yellow	*Orange to reddish brown
Red lead	Red	*Black (yields oxygen at a higher temperature)
Ferric oxide	Red	*Black
Zinc oxide	White	*Yellow
Stannic oxide	White	*Pale yellowish brown
Cadmium oxide	Brown	*Dark brown
Cuprous oxide	Reddish brown	Black
Tungstic oxide	Yellowish green	*Dark orange
Molybdic oxide	Pale yellowish green	*Orange
Titanic oxide	White	Yellow (at higher temperatures, brown)

* Indicates temporary change only.

(b) *Evolution of Gas*, or other volatile decomposition product.

Product and its detection	*Indicates*
Oxygen	Certain metallic oxides which decompose on heating into the metal and oxygen (*e.g.*, mercuric oxide, silver oxide), dioxides (*e.g.*, of manganese and lead) or peroxides (*e.g.*, of barium, calcium, and sodium), chlorates, bromates, perchlorates, percarbonates, persulphates, perborates, permanganates, and some nitrates and chromates.
Hydrogen.	Alkali formates.
Chlorine (**by greenish colour, bleaches litmus paper, and by smell**).	Platinic, auric, and certain other chlorides.
Hydrochloric acid (forms white fumes with ammonia).	Magnesium, barium, and certain other chlorides.
Bromine (brown fumes, characteristic odour).	Bromides in presence of oxidising substances.
Iodine (violet vapours, also given after mixing with ferrous sulphate).	Iodides, in presence of oxidising substances, or iodates.
Hydrofluoric acid (test-tube etched).	Certain fluorides in presence of water.
Ammonia (by smell and alkaline reaction to litmus paper).	Ammonium salts (other than nitrate and nitrite), and, under certain conditions, cyanides and cyanates. (*Note.*—Ammonium dichromate and chromate deflagrate vigorously on heating, evolving nitrogen and ammonia, and leaving a green residue of chromic oxide. Ammonium phosphate and borate leave glassy residues.)
Nitrogen (extinguishes burning splint).	Nitrites in presence of ammonium salts and moisture.
Nitrous oxide.	Ammonium nitrate.
Oxides of nitrogen (by reddish colour).	Nitrates of the heavy metals.
Carbon dioxide (by baryta water test), sometimes mixed with carbon monoxide.	Carbonates; carbon in presence of reducible oxides, or nitrates; cyanates.
Carbon monoxide (burns with blue flame), often mixed with carbon dioxide or hydrogen.	Oxalates.
Carbon disulphide (smell).	Thiocyanates of heavy metals.
Cyanogen (smell and carmine flame).	Cyanides of certain heavy metals; cyanates; thiocyanates.
Methane (luminous flame) accompanied by odour of acetone.	Acetates in presence of alkalies.

Product and its detection	*Indicates*
Sulphur dioxide (smell and reducing action).	Acid sulphites; sulphates of certain heavy metals; some thiosulphates; sulphur; sulphides; thiocyanates, etc., in presence of oxidising substances.
Sulphuric acid fumes.	Bisulphates.
Hydrogen sulphide (smell, and blackens lead acetate paper).	Sulphides, and thiosulphates in presence of water; hydrosulphites.
Hydrogen phosphide (by odour).	Phosphites, and hypophosphites.

(c) *Volatile product forms a sublimate.*

Sublimate collected and heated with a mixture of two parts of powdered charcoal and two parts of fusion mixture.

Substance	*Nature of Sublimate*	*On reheating as above*
Ammonium salt	White	Smell of ammonia; no sublimate
Mercuric chloride	White (substance melts readily)	
Mercurous chloride or bromide	White (substance does not melt)	Metallic mirror and globules of mercury
Mercuric nitrate, oxide, or cyanide	Metallic globules	
Mercuric iodide	Yellow, red on rubbing	
Mercuric sulphide	Black, and metallic globules	
Arsenious oxide (and hence arsenic oxide)	White, crystalline, deposited at distance from flame	Metallic mirror instantly dissolved by hypochlorite solution
Arsenious sulphide	Reddish yellow	
Antimony oxide	Glittering white needles, deposited near flame	Metallic mirror, very slowly dissolved by hypochlorite solution
Stibnite (antimony sulphide)	White	
Lead chloride	White (only formed at high temperature), fuses readily	
Sulphur, polysulphide, thiosulphate	Yellow, deep red drops when hot	
Iodine, certain iodides and iodates	Black, crystalline	
Oxalic acid	White crystalline, with white fumes	

TEST 2.

Substance is heated with potassium bisulphate.

In addition to results given by Test I (*b*) :

Oxygen (and red or green liquid).	Chromates.
Acid fumes (dense white fumes with ammonia).	Halides.
Chlorine dioxide (similar to chlorine, but explosive).	Chlorates.
Hydrofluoric acid (test-tube etched)	Fluorides, hydrofluosilicates.
Oxides of nitrogen.	Nitrites; nitrates (best in presence of copper).
Carbon monoxide (burns with blue flame).	Formates; oxalates; cyanides; ferrocyanides; ferricyanides.
Acetic acid (characteristic smell).	Acetates.

TEST 3.

Substance is moistened with pure, concentrated hydro-chloric acid and heated on a platinum wire in the non-luminous Bunsen flame.

Flame Coloration.	*Indicates*
Lavender violet.	Potassium.
Vivid bluish white.	Lead, arsenic, antimony.
Blue (afterwards green).	Copper.
Green.	Barium.
Faint yellowish green.	Molybdenum.
Yellowish green.	Boron, manganese chloride.
Golden yellow.	Sodium.
Carmine red.	Lithium.
Brick red.	Calcium.
Crimson.	Strontium.

In the case of substances such as barium sulphate, the flame coloration is best obtained by first heating the substance in the reducing flame and then moistening with hydrochloric acid. The boron flame is best given in presence of sulphuric acid, and, in presence of silicates, after admixture with calcium fluoride and potassium bisulphate.

Care should be taken to distinguish the above flame colorations from scintillations, such as are obtained with bismuth, zinc, etc., salts.

In presence of sodium, the potassium flame is masked, but is visible as a reddish violet through a blue cobalt (or better, a didymium) glass, which cuts out the sodium flame. This precaution does not, however, prevent the masking of the potassium flame in presence of strontium, lithium, and calcium. The strontium and calcium flames are sometimes masked by the presence of barium, and that of lithium by the sodium flame.

Traces of sodium are present in most compounds, and in testing for sodium the flame coloration should persist and should not be appreciably increased in intensity by mixing about 1 per cent. of sodium chloride with the original solid.

TEST 4.

A small fragment of the substance is heated with a colourless borax bead (1—1½ mm. diam.) on a platinum wire.

Oxides of	Oxidising flame		Reducing flame	
	Hot	Cold	Hot	Cold
Copper	Green	Bluish green	Colourless	Brown to red (cloudy)
Iron	Yellowish brown	Yellow or colourless	Bottle green	Bottle green
Chromium	Yellow or dark red	Yellowish green	Green	Emerald green
Manganese	Amethyst	Reddish violet	Colourless	Colourless
Cobalt	Blue	Blue	Blue	Blue
Nickel	Violet	Reddish brown	Grey (cloudy)	Grey (cloudy)
Molybdenum	Yellow to brown	Yellowish green to colourless	Dark brown	Green
Titanium	Colourless	Colourless	Yellow to brown	Violet
Uranium	Yellow	Yellowish green	Green	Bottle green
Vanadium	Brown to yellow	Greenish yellow	Brown	Bottle green

To cool beads from the reducing flame, they are held in the cold gas-mixture just above the Bunsen tube. Reduced beads of *uranium*, etc., are best obtained by introducing a fragment of stannous chloride into the bead. In the presence of iron (*e.g.*, in rutile), *titanium* gives a brownish-red bead.

The colours of the borax beads obtained with metallic sulphides and arsenides frequently differ from those given by the other salts and the oxides, *e.g.*, manganese sulphide gives a brown bead. If sulphide or arsenide is suspected, this difficulty may be overcome by fusing with a fragment of sodium peroxide.

TEST 5.

A fragment of the substance is introduced into a bead made from microcosmic salt.

In presence of *silica* or *silicates*, undissolved particles are noticed in the bead.

This metaphosphate bead gives similar colorations to the borax bead. The results given by *molybdenum* and *titanium* are more characteristic in the case of the metaphosphate bead. In the reducing flame *tungsten* gives a blue metaphosphate bead, which becomes blood-red on the introduction of ferrous sulphate.

TEST 6.

(a) A fragment of the solid is heated in an opaque bead of fusion mixture on a platinum wire.

Effervescence.	Silica, silicate; stannic, titanic, tungstic or molybdic oxides.
Yellow.	Chromate, dichromate.

(b) If (a) gives a white bead, it is re-heated with a fragment of sodium peroxide, or of potassium nitrate on platinum foil.

Yellow.	Chromium, vanadium.
Green.	Manganese.

TEST 7.

(a) The substance is heated in a clean cavity in a charcoal block in the oxidising flame.

In addition to results of Test 1 (a) :

Deflagration.	Nitrate, chlorate, etc
Intumescence.	Certain salts containing water of crystallisation, e.g. borax.
Infusible light powder.	Alumina.
Infusible white mass, incandescent whilst hot :	
Alkaline residue.	Barium, strontium, calcium, or magnesium oxide.
Neutral residue.	Zinc oxide.
Incrustation.	See Test 8.

(b) The mass from (a) is heated in the oxidising flame after moistening with two drops of cobalt nitrate solution.

A light powder (such as alumina) may be retained on the charcoal by first fusing with a small amount of fusion mixture.

Deep blue, fusible mass.	Phosphates, arsenates of sodium, potassium, calcium, strontium, and barium.
Blue.	Silica, silicate, borate, tungstate.
Light blue, infusible mass.	Aluminium.
Bluish green.	Tin.
Green	Zinc.
Yellowish green, infusible mass.	Titanium.
Dull green.	Antimony.
Pink (indistinct).	Magnesium.
Brown.	Barium.

TEST 8.

(a) In case substance has been found to deflagrate, it is first heated alone on charcoal.

Otherwise it is mixed directly with twice the amount of fusion mixture, and heated on charcoal in the reducing flame of the blow-pipe.

The product is crushed in water in a small mortar, and the washed particles tested for malleability, and with a magnetised penknife blade for magnetic properties. Colours of incrustation when hot and cold are to be compared with Test 1 (a).

Brilliant white malleable bead, dark red incrustation.	Silver.
Malleable white bead (marks paper), yellow incrustation.	Lead.
Brittle white bead, bluish white incrustation.	Antimony
Brittle white bead, yellow incrustation.	Bismuth.
Malleable white bead (slight yellow incrustation).	Tin.
Malleable red bead.	Copper.
Yellow bead.	Gold.
White incrustation. No bead.	Zinc.
Black incrustation, brown at edges. Yellow on fusing with anhydrous sodium thiosulphate. No bead.	Cadmium.
Deep blue incrustation.	Molybdenum.
Volatile white incrustation, garlic odour.	Arsenic.
Grey magnetic powder	Iron, cobalt, nickel.

The powder is separated by a magnetised blade, dissolved in dilute nitric acid in an evaporating dish, and solution evaporated just to dryness over a small flame.

Brown residue.	Iron.
Pink residue.	Cobalt.
Green residue.	Nickel.

(b) If (a) fails to give a bead, a fragment of potassium cyanide is added and the mass re-heated, when the tin and copper beads, for example, will be more easily obtained.

(N.B.—If found to be present by Test 2, nitrates must be destroyed by a preliminary heating, or the mixture may be explosive.)

Note.—The bead obtained may be an alloy, and the following tests may be used to confirm the test. The metallic bead is divided into two pieces, and tested on a watch-glass as follows :

I. One half is warmed with dilute nitric acid (1 : 4).

White residue.	Antimony, tin.
Soluble with difficulty.	Arsenic, bismuth, mercury.
Readily soluble.	Lead, cadmium, silver, copper.

(i) Solution is decanted from residue and separate portions spotted on watch-glasses with—

Dilute hydrochloric acid.	White precipitate in presence of silver or lead, and, at suitable concentrations, with bismuth.
Dilute sulphuric acid.	White precipitate in presence of lead.
Ammonia	Blue solution in presence of copper.
Ammonium sulphide.	Yellow precipitate in presence of arsenic; brighter yellow precipitate in presence of cadmium; black precipitate in presence of silver, lead, bismuth, or mercury.

(ii) Residue is treated with ammonium sulphide.

Brown.	Tin.
Orange.	Antimony.

II. If soluble, the remainder of bead is dissolved in hydrochloric acid (1:1), and mercuric chloride solution added.

White or grey precipitate.	Tin.

TEST 9.

The substance is mixed with slaked lime, and heated in an ignition tube.

Evolution of ammonia (smell and alkaline reaction).	Ammonium salt.
Evolution of methane (also smell of acetone).	Acetate.

TEST 10.

A lump of copper oxide held in a platinum wire is heated in the non-luminous Bunsen flame, some of the substance placed on the copper oxide and then heated.

Blue flame (afterwards green).	Chloride, bromide, or iodide.

TEST 11.

(a) Substance is placed on a piece of silver foil or a silver coin and moistened with a drop of water.

Black or brown stain on silver.	Sulphide.

(b) Substance is mixed with starch and fusion mixture and heated in an ignition tube. The mass is broken on a piece of silver foil or a silver coin and moistened with water

Black or brown stain on silver.	Sulphur in some form.

The presence of mercury interferes with this test.

TEST 12.

The residue obtained by igniting some of the substance on a crucible lid is powdered, a piece of magnesium ribbon added, and the mixture heated in a test-tube. The test-tube is broken in an evaporating dish, and moistened with water.

Evolution of spontaneously inflammable gas (smell of decayed fish).	Phosphate, or phosphorus in some other form.
Evolution of spontaneously inflammable gas (green flame).	Borate, or boron in some other form.

————

SOLUTION ANALYSIS.

The main points of interest in the theoretical considerations governing the use and value of the tests employed in solution analysis are : (1) the Theory of Ionic Dissociation, and its consideration in conjunction with the Law of Mass Action, and (2) the formation of Complex Salts.

According to the theory of ionic dissociation, the methods of solution analysis may be regarded as depending almost entirely on the chemistry of the *ions* and not of the *elements*. The characteristic reactions of ions containing the elements are used for the identification of the elements, and the condition in which they are present (*e.g.*, arsenic as chloride, or arsenate, etc.) In other words : *the properties of a dilute solution of a salt are, in general, the sum of the properties of its ions.*

The process of *neutralisation* is essentially an ionic reaction. The neutralisation depends on the combination of hydrogen ions (the presence of which is known as acidity) with hydroxyl ions (the presence of which is known as alkalinity) to form the practically non-ionised water.

A detailed account of the theory of ionic dissociation, the reasons for its adoption and its advantages as a working hypothesis, will be found in most text-books on theoretical chemistry.

Formation of Complex Ions.

On adding a solution of potassium iodide to a solution of mercuric chloride, the precipitate of mercuric iodide is found to be soluble in an excess of potassium iodide. The addition of caustic soda to this solution does not give a precipitate, whereas the addition of caustic soda to the mercuric chloride solution would give a precipitate. The reactions of salts in

solution have already been stated to be the sum of the reactions of their ions, and hence the mercuric ion must be absent from the former solution. This is considered to be due to the presence in the solution of a *complex ion*, $[HgI_4]$, which contains the mercury in a form in which it does not give the reactions of the mercuric ion, thus :

$$HgI_2 + 2KI = K_2[HgI_4].$$
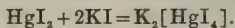
On ionisation, this compound will give $K^{\cdot}$ and $[HgI_4]''$ ions, but no Hg'' ions.

Similar considerations apply to many other halides, and to the cyanides. For example, a method frequently used for detecting cadmium in presence of copper (Group II separation) is to add potassium cyanide to the blue, ammoniacal solution until it has become decolorised, and then to pass in hydrogen sulphide to precipitate any cadmium present. [A disadvantage of this method is that, in presence of much copper, a red or orange precipitate of dithio-oxamide is obtained, and this may be mistaken for cadmium sulphide.] This method depends upon the solution of cupric cyanide in an excess of potassium cyanide to form a compound in which the copper is present in a colourless complex ion, from which it is not precipitated by hydrogen sulphide ; hence the disappearance of the characteristic blue colour of the cupric ion on addition of potassium cyanide.

In ammoniacal solution, copper is present in an intense blue complex ion $[Cu(NH_3)_4]$.

The so-called " platinic chloride," used in testing for potassium, is actually chlorplatinic acid $H_2[PtCl_6]$, in which the platinum forms part of a complex anion. The addition of the true platinic chloride ($PtCl_4$) to a solution of potassium chloride gives a precipitate only after standing for a considerable time, on account of the extremely slow formation of the potassium chlorplatinate, $K_2[PtCl_6]$, under these conditions. Similarly " auric chloride " is actually the compound chlorauric acid, $H[AuCl_4]$, and the colourless solution of cuprous chloride in hydrochloric acid contains a complex compound, probably $H_2[CuCl_3]$.

The *double salts* should be differentiated carefully from the *complex salts*. Whereas the latter contain complex ions in solution, solutions of double salts, such as the alums, give the same ionic reactions as the single salts. In this connection it is to be noted, however, that certain complex salts undergo a secondary dissociation, *e.g.*, solutions of ferrioxalates contain ferric and oxalate ions in addition to $[Fe(C_2O_4)_3]$ ions.

SOLUTION OF A SOLID SUBSTANCE.

The behaviour of the substance on warming with the following solvents should be examined :

(1) *Water.*

Evolution of	Indicates
Oxygen.	Peroxides of the alkali or alkaline earth metals.
Methane.	Aluminium and other carbides.
Acetylene.	Calcium and other carbides.
Ammonia.	Nitrides, metallic amides, cyanamides.
Hydrochloric acid.	Chlorides of certain non-metals.
Carbon dioxide.	Bicarbonate, or carbonate in presence of an acid or an acid salt.
Hydrogen phosphide	Phosphides of the alkali or alkaline earth metals.
Hydrogen sulphide.	Sulphides of magnesium, aluminium, etc.

(2) *Dilute hydrochloric acid.*

Evolution of	Indicates
Hydrogen.	Presence of a metal.
Oxygen.	Peroxide.
Chlorine.	Presence of an oxidising agent.
Oxides of nitrogen.	Nitrite.
Carbon dioxide.	Carbonate, percarbonate, cyanate.
Methane, acetylene, etc.	Carbide.
Acetic acid.	Acetate.
Sulphur dioxide.	Sulphite.
Sulphur dioxide and liberation of sulphur.	Thiosulphate.
Hydrogen sulphide.	Sulphide, hydrosulphite.
Hydrogen sulphide and liberation of sulphur.	Polysulphide.
Hydrogen cyanide.	Cyanide, ferrocyanide, ferricyanide.

(3) *Concentrated hydrochloric acid.* As certain metallic chlorides are volatile with hydrochloric acid, such a solution may be warmed, but should not be boiled.

(4). *Dilute nitric acid.* In addition to the behaviour observed in (2) :

Evolution of nitrous fumes.	Presence of metal.

(5) *Concentrated nitric acid.* Mercurous chloride dissolves as mercuric nitrate, and hence the state of the mercury must be ascertained by testing in the original solid (*e.g.*, blackening by ammonia indicates mercurous chloride).

Solutions in nitric acid should be evaporated almost to dryness before proceeding with the analysis. It is to be remembered that sulphides, etc., have probably been oxidised by the treatment with nitric acid.

(6) *Concentrated sulphuric acid* decomposes complex cyanides.

(7) *Aqua regia.* (One vol. of concentrated nitric acid to four vols. of concentrated hydrochloric acid). This should only be used if all the above solvents have failed.

All solutions in strong acids must be diluted with five or six times their volume of water before proceeding to the group tests.

White precipitate on dilution, soluble in hydrochloric acid.	Antimony or bismuth (the former only is soluble in tartaric acid).

In case it is not found possible to dissolve the whole of the substance, a portion may have been dissolved by one of the above solvents (as found by carefully evaporating some of the filtrate to dryness at the lowest possible temperature). The solution obtained is used for the group tests, and the residue examined by the special tests for insoluble substances.

EXAMINATION OF A SOLUTION.

General tests.

(*a*) Unless the solution has been made by dissolving a substance in an acid as above, its smell should be noted, and it should be tested with litmus paper.

Alkaline solution.	Presence of an alkali, basic salt, hydrolysed salt of a strong base with a weak acid (normal alkali carbonate, alkali borate, cyanide, sulphide, silicate, hypochlorite, commercial alkali nitrate, trimetallic phosphate, stannate, antimonate, zincate, molybdate, or tungstate).
Acid solution.	Presence of an acid, acid salt (bisulphate, bicarbonate, acid phosphate, dichromate) or hydrolysed salt of a strong acid with a weak base (cupric, ferric, etc. salts).

(b) It is useful, though not conclusive, to note the colour of the solution; the following is a list of the commoner colour ions :

	Cations		Anions
Lilac	Titanous	Purple	Permanganate
Blue	Cupric, tungstous, molybdenous	Green	Manganate, ferri-cyanide
Green	Cupric, cuprous, nickel, ferrous, chromic	Orange	Dichromate
		Yellow	Chromate, ferrocyanide
Yellow	Ferric, uranium		
Pink	Cobalt, manganese		

In addition, bromine solution is orange, and a solution of iodine in an iodide is brown.

(c) A small portion is evaporated to dryness and examined by dry-way tests. In case no residue is obtained, and solution is acid, it is neutralised with sodium carbonate and tested for acids.

(d) *Special tests for Hydrogen peroxide.*

(1) In case solution is slightly alkaline, cobalt nitrate solution is added. Black precipitate in absence of hypochlorite and sulphide (which could not co-exist with hydrogen peroxide, as they would be reduced to chloride and oxidised to sulphate respectively) indicates hydrogen peroxide.

(2) Solutions of gold are reduced to the metal, with liberation of oxygen, at the ordinary temperature by alkaline hydrogen peroxide.

(3) In the case of an acid solution, titanium sulphate is added. A yellow coloration due to the formation of per-titanic acid indicates the presence of hydrogen peroxide, in absence of chlorate.

(4) The dichromate test is also available for the detection of hydrogen peroxide in acid solution, provided that a "blank" is carried out. The solution is acidified with sulphuric acid and potassium dichromate solution added. The liquid is shaken with ether, when a blue ethereal layer, due to perchromic acid, indicates the presence of hydrogen peroxide.

Tests for Ozone. Ozone does not (1) give a yellow coloration with titanium sulphate, or (2) precipitate gold from solutions of its salts, but (1) liberates iodine *immediately* from dilute *neutral* potassium iodide solution, (2) liberates bromine immediately from an acidulated solution of sodium bromide, and (3) immediately turns silver foil heated to 250° steel blue (this reaction does not occur in the cold unless the silver foil has been treated with nitric acid, or has been cleaned

with emery paper, the iron oxide in which appears to act as a catalyst). These latter reactions are not given by hydrogen peroxide.

(e) *Detection of free Alkali.*

After destroying hydrogen peroxide by boiling, the presence of free alkali, possibly formed by the hydrolysis of an alkali peroxide, in an alkaline solution may be detected in presence of an alkali carbonate by adding an excess of barium chloride and filtering to remove the barium carbonate precipitated. Alkaline filtrate indicates presence of free alkali.

I. Acid Radicals (Anions).

TEST 1.

The substance is warmed with dilute sulphuric acid :

Evolution of	*Indicates*
Hydrogen.	A metal.
Oxygen.	Peroxide.
Chlorine.	Hypochlorite, or chloride in presence of an oxidising agent.
Oxides of nitrogen.	Nitrite.
Carbon dioxide.	Carbonate, percarbonate, cyanate.
Methane, acetylene, etc.	Carbide.
Acetic acid.	Acetate.
Sulphur dioxide.	Sulphite.
Sulphur dioxide and liberation of sulphur.	Thiosulphate, thiocyanate.
Hydrogen sulphide.	Sulphide.
Hydrogen sulphide and liberation of sulphur.	Polysulphide, hydrosulphite.
Hydrogen cyanide.	Cyanide, ferrocyanide, ferricyanide.

TEST 2.

The substance is heated with concentrated hydrochloric acid :

Evolution of	*Indicates*
Chlorine.	Presence of an oxidising agent, *e.g.*, dioxide, chlorate, nitrate, persulphate, chromate, dichromate, permanganate.
Carbon dioxide and hydrogen sulphide.	Thiocyanate.

TEST 3.

A small amount of the substance is warmed very cautiously with a few drops of concentrated sulphuric acid. In addition to results in Test 1 :

Evolution of	*Indicates*
Oxygen (frequently mixed with ozone).	⌐ioxide, permanganate, dichromate, chromate, persulphate.
Hydrochloric acid.	Chloride.
Chlorine.	Chloride in presence of an oxidising agent.
Chlorine dioxide (explosive).	Chlorate.
Chromyl chloride (colours nonluminous Bunsen flame white).	Chloride in presence of a chromate.
Bromine.	Bromide or bromate.
Iodine.	Iodide or iodate.
Silicon fluoride.	Fluoride, hydrofluosilicates.
Oxides of nitrogen.	Nitrate.
Sulphur dioxide.	Metal, sulphide, carbon in some form.
Sulphur dioxide and liberation of sulphur.	Thiosulphate, thiocyanate.
Sulphur dioxide and hydrogen sulphide, in addition to iodine.	Iodide.
Carbon monoxide.	Cyanide, ferrocyanide.
Carbon dioxide and monoxide (without blackening).	Ferricyanide, oxalate.
Carbon dioxide and monoxide, and sulphur dioxide (with blackening).	Tartrate.

TEST 4.

The substance is heated with manganese dioxide and dilute sulphuric acid. In addition to results in Test 3 :

Chlorine.	Chloride.
Bromine.	Bromide.
Iodine.	Iodide.

TEST 5.

Substance or solution is boiled with an excess of sodium carbonate* solution for five minutes, and filtered if necessary. The clear filtrate is divided into three portions, and treated as follows :

(1) One portion is neutralised by adding dilute nitric acid†

* Chloride and sulphate are frequently present in traces in sodium carbonate, and hence a "blank" should be carried out, unless the precipitates obtained (with silver nitrate and barium chloride respectively) are very definite.

† On acidifying with nitric acid, any sulphite, sulphide, etc., in the solution may be decomposed. A precipitate may be obtained in presence of certain sulphur cids, silicates, tungstates, molybdates, zincates, stannites, stannates, etc. The ppt. is examined by the dry-way tests, and the filtrate tested for acid radicals.

slowly until no more effervescence occurs on further addition, then ammonium carbonate added again until no further effervescence occurs, and the liquid boiled for several minutes to destroy the excess. The neutral solution is treated with:

Silver nitrate solution. After filtering, the behaviour of portions of the precipitate towards hot water, dilute nitric acid, and ammonia is examined. In case the nitric acid appears to dissolve any of the precipitate, the liquid is filtered, and ammonia added carefully to the filtrate to reprecipitate the silver salt, which may probably be identified by the colour of the ring produced.

White precipitate:

Soluble in hot water.	Sulphate, nitrite, acetate, benzoate, salicylate.
Decomposed by acetic acid.	Silicate
Insoluble in dilute nitric acid:	
Soluble on heating. Solution in ammonia (1 : 20) gives yellow precipitate on addition of sulphur dioxide.	Bromate, iodate.
Curdy precipitate, soluble in ammonia.	Chloride, hypochlorite, cyanide, thiocyanate.
Insoluble in ammonia, soluble in potassium cyanide, becomes orange and soluble in ammonia on boiling with concentrated nitric acid.	Ferrocyanide.
Soluble with difficulty in nitric acid.	Selenite.
Soluble in nitric acid and in ammonia:	
Curdy precipitate.	Cyanate, pyrophosphate, molybdate, oxalate.
Curdy precipitate, solution in ammonia deposits silver on warming.	Tartrate.
Amorphous precipitate.	Metaphosphate.
Amorphous precipitate, becomes brown on warming.	Borate.
Crystalline precipitate, becomes black on warming.	Sulphite, thiosulphate, formate, citrate.

Pale yellow precipitate:

Insoluble in dilute nitric acid and in very dilute ammonia (1 : 20).	Bromide.

Yellow precipitate:

Insoluble in dilute nitric acid and in ammonia.	Iodide.
Soluble in nitric acid and in ammonia:	
Insoluble in acetic acid.	Phosphate.
Soluble with difficulty in acetic acid; solution in ammonia deposits silver on warming.	Arsenite.
Curdy, brownish precipitate.	Vanadate.

Orange precipitate :
  Insoluble in dilute nitric acid, soluble in ammonia and in potassium cyanide. — Ferricyanide

Chocolate brown precipitate :
  Soluble in nitric acid and in ammonia, insoluble in acetic acid. — Arsenate.

Reddish brown precipitate :
  Soluble in nitric acid and in ammonia, insoluble in acetic acid. — Chromate.

Black precipitate :
  Insoluble in cold, dilute nitric acid, dissolves on warming. — Sulphide, hydrosulphite.
  Soluble in cold, dilute nitric acid. — Phosphite, hypophosphite.

- (2) Another portion is neutralised as in (1), using hydrochloric acid in place of nitric acid, and the neutral solution divided into three portions. To these are added :

(a) *Calcium chloride solution.*

  White crystalline precipitate, soluble in concentrated hydrochloric acid — Sulphate or sulphite (in considerable amount).

  White precipitate, soluble in acids. — Phosphite.

  White precipitate, decomposed by acetic acid. — Silicate.

  White precipitate, soluble in excess of pyrophosphate. — Pyrophosphate.

  White amorphous precipitate, soluble in acetic acid and in ammonium chloride. — Borate.

  White amorphous precipitate, (gelatinous in presence of ammonia), soluble in acetic acid. — Phosphate, arsenate, arsenite.

  White amorphous precipitate, soluble in hydrochloric acid (reprecipitated by ammonia), insoluble in acetic acid. — Oxalate.

  White gelatinous precipitate, soluble in acetic acid (until the precipitate has become crystalline). Soluble in caustic potash, precipitated on warming, redissolves on cooling. — Tartrate.

  White gelatinous precipitate, soluble with difficulty in dilute hydrochloric acid, insoluble in acetic acid, soluble in ammonium chloride. — Fluoride.

  White precipitate, less soluble in hot water than in cold, insoluble in caustic potash, soluble in ammonium chloride. — Citrate.

  White precipitate on warming. — Ferrocyanide

  White precipitate on addition of alcohol. — Malate

(b) *Barium chloride solution.*

White precipitate, soluble in hydrochloric acid.	Sulphite, selenite, phosphate, arsenate, arsenit, borate, bromate, iodate. periodate, pyrophosphate molybdate, vanadate, oxalate, tartrate.
(If sulphite is present, addition of bromine water to solution of precipitate in hydrochloric acid gives precipitate of barium sulphate.)	
White precipitate, soluble in excess of metaphosphate and in hydrochloric acid.	Metaphosphate.
White precipitate decomposed by acetic acid.	Silicate.
White precipitate, soluble in acetic acid.	Phosphite.
White, crystalline precipitate almost insoluble in dilute hydrochloric acid.	Hydrofluosilicate.
White, voluminous precipitate, soluble with difficulty in hydrochloric acid.	Fluoride.
White precipitate, insoluble in concentrated hydrochloric acid.	Sulphate.
White precipitate, insoluble in nitric acid, soluble in hydrochloric acid.	Selenate.
White precipitate on boiling.	Persulphate, ferrocyanide.
White precipitate in concentrated solution.	Thiosulphate.
Yellow precipitate, soluble in dilute hydrochloric and nitric acids, insoluble in acetic acid.	Chromate, dichromate.

(c) *Ferric chloride solution.*

Blue precipitate.	Ferrocyanide.
Red solution, brown precipitate on boiling.	Acetate.
Pink precipitate, soluble in hydrochloric acid, white crystals on cooling.	Benzoate.
Light yellow precipitate.	Succinate.
Pale yellow precipitate, insoluble in acetic acid.	Phosphate.
Dark brown solution.	Ferricyanide.
Blood-red coloration, extracted by ether, destroyed by mercuric chloride but not by hydrochloric acid	Thiocyanate.
Transitory claret coloration, destroyed by acids.	Thiosulphate.
Deep violet coloration.	Salicylate.

(3) A further portion of filtrate is acidified with dilute sulphuric acid, an equal volume of ferrous sulphate solution added, and concentrated sulphuric acid carefully poured into the test-tube to form a layer :

Brown ring.	Nitrate, nitrite.
Violet ring.	Iodide.
Red coloration at bottom of sulphuric acid layer).	Bromide.

CONFIRMATORY TESTS FOR CERTAIN ACID RADICALS.

Chlorides, Bromides and Hypochlorites.

On distilling a chloride with sulphuric acid and a chromate, chromyl chloride volatilises, and on collecting in water, is hydrolysed to chromate, which may be detected after neutralising. Bromides give free bromine, which may be identified after conversion into bromide by means of ammonia.

In presence of free chlorine, hydrochloric acid may be detected by shaking with mercury to free from chlorine, and testing for acidity and chloride in the filtrate. If hypochlorous acid is present, the precipitate obtained with the mercury will be brown.

Manganese sulphate gives a black precipitate in alkaline solution with hypochlorites. (Chlorates do not exert their oxidising power in alkaline solution.)

Chlorates.

(1) Dilute sulphuric acid liberates chloric acid, which gradually decomposes into perchloric acid and chlorine, and hence colours starch-iodide paper blue after standing a short time.

(2) On addition to a solution of titanous chloride, an orange solution is produced.

(3) Indigo carmine solution is bleached in the cold by *chlorate* in presence of sulphur dioxide, the presence of which is not necessary in the case of a warm solution of a *nitrate* acidified with sulphuric acid.

Perchlorates.

(1) On reduction with titanous sulphate, or by digesting in alkaline solution with ferrous hydroxide, chlorides are produced.

Chlorides are also produced on ignition, alone or in presence of an alkali nitrite.

(2) Concentrated solutions give a white, crystalline precipitate on addition of a concentrated solution of potassium chloride.

Bromates.

Sulphurous acid, hydrogen sulphide, zinc and an acid, etc., give bromide.

Iodates.

(1) Hydriodic acid, or acidified potassium iodide, reduces iodic acid with liberation of iodine.

(2) Sulphurous acid causes the liberation of iodine.

(3) Pyrogallol solution gives a brown solution (not given by chlorates or bromates).

Nitrates.

(1) Iodine is not liberated from dilute solutions of potassium iodide acidified with acetic acid until a fragment of zinc is added to reduce to nitrite.

(2) The solution under examination is mixed with three times its volume of pure, concentrated sulphuric acid, and 1 cc. of a brucine solution (0·2 grm. in 100 cc. of pure, concentrated sulphuric acid) added. Nitrates give a red coloration which rapidly changes through orange and golden yellow to yellowish green. (*Note*.—As nitrites decompose and give small amounts of nitrates on addition of sulphuric acid, they also give the brucine test.)

(3) A dilute acetic acid solution of "nitron," diphenylendanilo-dihydrotriazole, gives a white, crystalline precipitate with very dilute solutions (also given by tungstates).

(4) In absence of nitrites, nitrates may be identified, after reduction to ammonia, by Nessler solution.

(5) Indigo (carmine) solution is decolorised by free nitric acid.

Detection of Nitrate in Sulphuric Acid.

Although the diphenylamine test is given by many oxidising substances other than nitrates (nitrites, chlorates, etc.), it is available for the detection of traces of nitrogen acids in concentrated sulphuric acid in absence of ferric salts and of selenic acid. The reagent is prepared by dissolving 0·5 grm. of diphenylamine in 100 cc. of pure, concentrated sulphuric acid, and adding carefully 20 cc. of water. This solution is carefully poured on to the acid under examination. On standing for several minutes, the presence of nitrogen acids is shown by the production of a blue ring.

Nitrites.

(1) Solutions acidified with sulphuric acid decolorise potassium permanganate.

(2) On addition of acidified potassium iodide, iodine is liberated, soluble in carbon disulphide to a violet solution. Detection of the iodine with starch renders this the most delicate test for nitrite in absence of other oxidising agents.

(3) The production of intensely coloured azo-compounds constitutes an extremely delicate test for nitrites in water, etc., in which case the potassium permanganate test fails, as traces of hydrogen peroxide and of ferric salts may be present.

The original reagent, suggested by Griess, was *meta*-phenylenediamine, which gives a yellow coloration or brown precipitate in presence of hydrochloric acid.

A more delicate test is to add 2 cc. of an acetic acid solution of sulphanilic acid and α-naphthylamine, when within five or ten minutes a mere trace of nitrite will produce a red solution. The reagent is prepared as follows : 0·5 grm. sulphanilic acid are dissolved in 150 cc. of dilute acetic acid ; 0·2 grm. of α-naphthylamine are extracted with 20 cc. of water, the colourless solution decanted, and mixed with 150 cc. of dilute acetic acid. The two solutions are mixed, and preserved in the dark.

Carbonates.

A suitable apparatus for the detection of traces of carbonate is shown in the sketch. D is a boiling tube, containing the
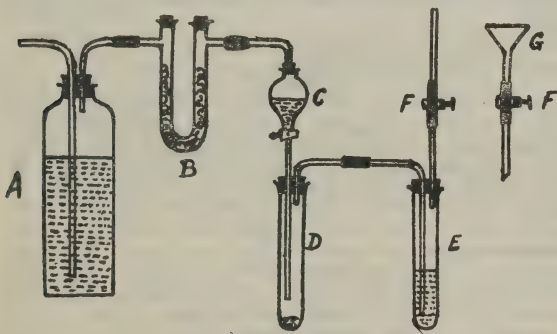
substance under examination, and fitted with a two-holed rubber stopper. Through one hole passes the stem of a small tap-funnel, C, the stopper of which is removed, and the top connected to a soda-lime tube, B, and this to a wash-bottle, A, containing caustic potash solution. D is connected to another boiling tube, E, as shown, which in turn is connected to a small piece of rubber tubing and screw-clamp, F. F serves to connect the boiling tube E either to the pump, or to the funnel, G. At first, both C and E are empty. The screw-clamp, F, is opened, and a slow current of air, freed from carbon dioxide, drawn through the apparatus for five minutes. The screw-clamp is closed, and the funnel G, fitted with a filter paper, inserted, and a suitable volume of baryta water poured on to the filter-paper. The tap-funnel is closed, and the soda-lime tube and wash-bottle disconnected. F is opened, and

the tap-funnel adjusted so that the baryta-water filters into the tube E. The tap-funnel and F are closed, the funnel G removed, and the apparatus again connected to the vacuum pump. About 10 cc. of dilute hydrochloric acid are introduced into the tap-funnel, which is then connected to the soda-lime tube and wash-bottle again, F is opened, and the tap-funnel adjusted so that the acid is drawn into D. A slow current of air is drawn through the apparatus for five minutes. The screw-clamp is closed, and any barium carbonate formed is easily detected by placing a piece of black paper under the boiling tube.

Percarbonates.

(1) On standing in solution, hydrogen peroxide and a bicarbonate are produced, and may be detected by the usual methods.

(2) Addition of the solid to a 25 per cent. solution of potassium iodide liberates iodine.

Cyanides.

(1) After evaporation of a cyanide with a few drops of yellow ammonium sulphide, free from thiosulphate (see Reagents), on a watch-glass, and acidifying with hydrochloric acid, ferric chloride gives a blood-red coloration.

(2) Addition of a small amount of ferrous sulphate to an alkaline solution converts cyanide into ferrocyanide, which may be detected by ferric chloride after acidifying with hydrochloric acid.

Ferrocyanides.

Insoluble ferrocyanides, such as Prussian blue, are identified after digesting with caustic soda.

Ferricyanides.

(1) Ferricyanides give a blue precipitate on addition of an acid solution of ferrous sulphate.

(2) Cadmium chloride gives a white precipitate insoluble in acids (not given by thiocyanates).

Cyanates.

(1) Dilute sulphuric acid gives carbon dioxide and ammonia, together with undecomposed cyanic acid, which has a pungent odour. The ammonium sulphate produced may be detected by warming with caustic soda solution.

(2) Cyanates may be detected in commercial cyanides by passing carbon dioxide into the solution to free from hydrocyanic acid, and then adding 25 cc. of alcohol to 1 cc. of the liquid to precipitate the carbonate. Addition of an alcoholic solution of cobalt acetate to the filtrate acidified with several drops of acetic acid gives a blue coloration (also given by thiocyanates).

Thiocyanates (Sulphocyanides).

(1) Mercuric nitrate gives white precipitate, soluble in excess of thiocyanate.

(2) Zinc and sulphuric acid give hydrogen sulphide.

See also cyanates (2).

Sulphates.

Benzidine hydrochloride gives a white precipitate of the sulphate (also given by tungstates).

Sulphites.

(1) Acidified potassium permanganate solution and iodine solution are decolorised; chromates are reduced to green chromium salts.

(2) Sodium nitroprusside gives a pink coloration which becomes red on addition of zinc sulphate. The reaction is made more delicate by adding a few drops of potassium ferrocyanide, when a red precipitate is obtained (not given by thiosulphates).

(3) Zinc and dilute sulphuric acid give a yellow coloration due to the production of hydrosulphurous acid. The same result is obtained on addition of a solution of a titanous salt.

(4) Stannous chloride gradually gives a yellow precipitate.

Sulphides.

(1) Lead nitrate, to which an excess of caustic soda has been added to give a clear solution, gives a black precipitate.

(2) Alkaline solutions give a reddish-violet coloration with a dilute solution of sodium nitroprusside.

(3) The most delicate reaction for hydrogen sulphide in water from mineral springs, etc., is the formation of methylene blue. To the liquid under examination is added one-tenth of its volume of concentrated hydrochloric acid and a small amount of dimethyl-*para*-phenylenediamine sulphate, the solution stirred, and then one or two drops of ferric chloride solution added. In the presence of amounts much less than those which can be detected by tests (1) or (2), a blue colour is produced after standing for half an hour.

Thiosulphates.

(1) Iodine solution is decolorised.

(2) On heating with zinc and hydrochloric acid, hydrogen sulphide is produced (also given by sulphites).

(3) Silver chloride and iodide, mercurous chloride, lead sulphate, etc., are dissolved by solutions of alkali thiosulphates.

Persulphates.

(1) Dilute solutions decompose, a large amount of ozone being formed, which may be detected by means of starch-iodide paper.

(2) In presence of an alkali, a black precipitate is obtained on addition of manganese, cobalt, etc., salts. (Persulphates are distinguished from hydrogen peroxide in that they do not decolorise permanganate solutions nor colour titanium sulphate solution yellow, nor give a blue colour with chromic acid and ether, except on standing or on heating in solution, when hydrogen peroxide is produced.)

(3) Barium chloride does not give a precipitate with fresh solutions, but on standing, more rapidly on boiling, sulphate is formed and a precipitate is obtained.

Hydrosulphites.

(1) Hydrosulphurous acid, produced by the addition of a dilute acid, forms a yellow solution.

(2) Ammoniacal cupric sulphate gives a yellowish-red precipitate of cuprous hydride.

(3) Alkaline solutions decolorise acidulated indigo carmine; the solution obtained becomes blue on exposure to air on filter-paper.

Selenates.

Hydrogen sulphide gives with warm solutions SeO_2, which then gives a yellow precipitate, soluble in ammonium sulphide.

Selenites.

(1) Sulphurous acid gives a red precipitate.

(2) Copper sulphate gives a greenish-blue precipitate.

(3) Hydrogen sulphide gives a lemon-yellow precipitate, soluble in ammonium sulphide.

Orthophosphates.

(1) Magnesia mixture gives a white crystalline precipitate with ammoniacal solutions. The precipitation of Group III metals in this test may be prevented by the addition of ammonium citrate to the solution.

(2) Ammonium molybdate (see Reagents) gives a yellow precipitate with acid solutions.

(3) Lead acetate gives a white precipitate practically insoluble in acetic acid.

(4) Uranyl acetate gives a yellow precipitate, insoluble in acetic acid.

Metaphosphates.

(1) Magnesia mixture does not give a precipitate with dilute solutions in presence of sufficient ammonium chloride and ammonia, in the cold or on boiling.

(2) Ammonium molybdate gives a precipitate only after boiling the solution with acids to convert into orthophosphoric acid.

(3) The free acid coagulates albumen, and hence the alkali salts behave similarly on addition of acetic acid.

Pyrophosphates.

(1) Magnesia mixture gives a white precipitate, soluble in excess of magnesium salt or of the pyrophosphate, but which is permanently precipitated by boiling.

(2) Ammonium molybdate behaves as with metaphosphates.

(3) Pyrophosphoric acid does not coagulate albumen.

Phosphites.

(1) Mercuric chloride is reduced to mercurous chloride, and to mercury by excess.

(2) On evaporation, solution gives phosphoretted hydrogen.

(3) Zinc and an acid give phosphoretted hydrogen.

Hypophosphites.

Silver, copper, gold and mercury salts are reduced to metal.

Borates.

(1) The substance is mixed with calcium fluoride and concentrated sulphuric acid, and a platinum wire moistened in the mixture is held in the lower part of a bunsen flame, which is coloured green in presence of boron.

(2) On immersing turmeric paper in a solution containing free boric acid, no change occurs until the paper is carefully dried, when it becomes reddish-brown, and this colour is not changed by dilute hydrochloric or sulphuric acid (difference from the colour produced by alkalies), but is turned bluish-black by caustic alkalies.

Note.—This test is also given by hydrochloric acid solutions of molybdic and titanic acids.

(3) Concentrated solutions give a precipitate of boric acid with hydrochloric acid.

Silicates.

(1) On evaporating to dryness with hydrochloric acid, a residue of silicic acid is obtained, which becomes blue on heating with cobalt nitrate on charcoal.

(2) The addition of an ammonium salt precipitates gelatinous silicic acid.

Hydrofluosilicates (Silicofluorides)

(1) Potassium chloride gives a gelatinous precipitate of potassium hydrofluosilicate in presence of an equal volume of alcohol.

(2) Ammonia gives a precipitate of silicic acid.

(3) On heating with concentrated sulphuric acid in a *platinum* vessel, silicon fluoride is produced (not given by fluorides), and may be detected by the formation of a white precipitate on the end of a moist glass rod held in the vapour.

Arsenites.

(1) In presence of sodium bicarbonate, iodine solution is decolorised.

(2) On warming with copper foil and hydrochloric acid, a deposit of copper arsenide is obtained (not given by arsenates).

(3) In presence of concentrated hydrochloric acid, stannous chloride gives a black precipitate on warming. (Also given on addition of titanous chloride.)

(4) Copper sulphate gives a green precipitate on addition of ammonia, soluble in excess. This precipitate of cupric hydrogen arsenite forms (red) cuprous oxide on heating with caustic soda solution.

Arsenates.

(1) In presence of ammonia and ammonium chloride, magnesium chloride gives a white, crystalline precipitate (not given by arsenites).

(2) In presence of a large excess of ammonium molybdate, (see Reagents), a yellow, crystalline precipitate is obtained on boiling (also given by arsenites, due to their oxidation to arsenate by the nitric acid in the ammonium molybdate reagent).

(3) Hydrogen sulphide first gives a white precipitate of sulphur in presence of hydrochloric acid and then a bright yellow precipitate of arsenic sulphide.

Antimonates.

On addition of potassium iodide to an acid solution, iodine is liberated. This test is not given by the alkali metantimonites, which contain Sb^{ii} in place of Sb^{v}. In alkaline solution, antimonates give with silver nitrate a black precipitate of silver oxide, soluble in ammonia, whereas the metantimonites give a precipitate which is not completely soluble in ammonia as it also contains metallic silver.

Chromates.

(1) After boiling with hydrochloric acid and alcohol, ammonia gives a bluish-green precipitate.

(2) The test for hydrogen peroxide, involving the production of perchromic acid, may also be used in identifying chromates after addition of sulphuric acid. Traces of chromate can only be detected by using ether free from alcohol.

Formates.

Mercuric chloride gives a precipitate of mercurous chloride.

Acetates.

(1) On warming the solid with a mixture of one part of alcohol and two parts of concentrated sulphuric acid, the smell of ethyl acetate is produced.

(2) On heating with arsenious oxide give cacodyl oxide (*extremely poisonous*)

Oxalates.

(1) Calcium chloride gives a white precipitate, soluble in dilute hydrochloric and nitric acids (reprecipitated by ammonia), but insoluble in acetic acid.

(2) On warming in presence of sulphuric acid, dilute potassium permanganate is decolorised.

(3) On heating with manganese dioxide and sulphuric acid, carbon dioxide is produced.

Tartrates.

(1) Calcium chloride gives a white precipitate, which only forms slowly in dilute solutions (especially in presence of ammonium chloride). The precipitate is soluble in acetic acid, and after washing is dissolved by cold caustic alkalies, being reprecipitated on heating, and redissolved on cooling.

(2) Silver nitrate gives a white precipitate. The supernatant liquid is decanted, water added, and precipitate dissolved in *just sufficient* very dilute ammonia. On placing the solution in a water-bath at 60–70°C., a silver mirror is formed.

Note.—In presence of other acids (except borate), tartrates may be precipitated by adding solid potassium carbonate to a concentrated solution until alkaline, and carefully acidifying with glacial acetic acid. The precipitated acid potassium tartrate is washed, dissolved in dilute caustic soda, neutralised, and the test carried out as in (2) above.

(3) A neutral or acid solution, to which has been added a small amount of ferrous sulphate, gives, on addition of a few drops of hydrogen peroxide, and then an excess of caustic

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soda, a deep violet or blue coloration, intensified by addition of two or three drops of ferric chloride.

(4) On warming with a 1 per cent. solution of resorcinol in concentrated sulphuric acid, a red coloration is produced.

Tartrates, Malates and Citrates.

In presence of these hydroxy-acids, ferric chloride does not give a precipitate on addition of alkali.

SPECIAL SEPARATIONS OF ACID RADICALS.

Chloride, Bromide, Iodide and Cyanide.

If a preliminary test with chlorine water has shown that a halide other than chloride is present, it is necessary to proceed as follows :

If present, *cyanide* is precipitated by adding a slight excess of nickel sulphate to neutral solution (*ferricyanides* are precipitated afterwards by adding ferrous sulphate) ; it is then boiled with a small amount of halogen-free caustic soda, and filtered. The filtrate is acidified with dilute sulphuric acid, and divided into two portions.

One portion of the acidified solution and a layer of chloroform are poured into a test-tube, and chlorine water added gradually, shaking after each addition. Violet solution indicates *iodide*. (Traces of iodide in presence of bromide are best detected by adding nitrite to a solution containing sulphuric acid, when only iodine is liberated.) Further addition of chlorine water decolorises the chloroform solution, which, however, becomes orange in presence of *bromide*.

On gradual addition of silver nitrate to the other half of the acidified filtrate, bromide and iodide are first precipitated, and by filtration after each addition of silver nitrate the presence of *chloride* is shown by the final precipitate being white.

Halides and Thiocyanate.

These are first precipitated with an excess of silver nitrate, and the precipitate digested on a water-bath with concentrated nitric acid for an hour, when only the silver halides remain undissolved.

Chloride, Chlorate and Perchlorate.

The *chloride* is precipitated in one portion of solution by adding an excess of silver nitrate ; after filtering, the filtrate is acidified with sulphuric acid, a small piece of zinc added, and warmed. White precipitate indicates *chlorate*. The remainder of the solution is reduced with sulphur dioxide, excess boiled off, and all chloride present precipitated as silver chloride. The filtrate is tested for *perchlorate*.

Chlorate and Hypochlorite.

Chlorate prepared by the electrolytic process may be tested for traces of hypochlorite by adding to 100 cc. of a 1 per cent. solution, prepared in the cold, 5 cc. of a mixture of a 10 per cent. cadmium iodide solution and a starch solution. Traces of hypochlorite immediately produce a blue colour.

(Hypochlorites give a precipitate of silver chloride on addition of silver nitrate or sulphate, but the solution then contains silver chlorate.)

Iodide and Iodate.

Iodide is tested for by means of fresh (neutral) chlorine water and carbon disulphide (chloroform is generally acid). Liberation of iodine on acidifying in presence of an iodide, indicates *iodate* (in absence of other oxidising agents).

Chlorate and Nitrate.

Solution is boiled with caustic soda to free from ammonium salts, aluminium dust added, and solution boiled. Evolution of ammonia indicates *nitrate* (also given by nitrite). Solution is acidified, and tested for chloride, the presence of which indicates *chlorate* in absence of chloride in the original (if present, chloride is eliminated by means of silver sulphate).

Nitrite and Nitrate.

Moderate amounts of *nitrite* are readily detected by means of potassium permanganate or iodide in presence of sulphuric acid.

On acidifying a solution of ferrous sulphate with dilute sulphuric acid and carefully pouring the solution on to the surface, a brown ring is formed in presence of a *nitrite*. The detection of *nitrate* by this test necessitates the use of concentrated sulphuric acid, and the test may be carried out after destroying the nitrite by boiling with ammonium chloride, or with a concentrated solution of urea in presence of sulphuric acid. (*Note.*—Traces of nitrate may be formed by oxidation during this process.)

Meta-phenylenediamine, or, better, the sulphanilic acid and α-naphthylamine reagent (see Reagents), is used for detecting *nitrite*.

Brucine may be used for detecting *nitrate* (see note above; the reaction between nitrite and concentrated sulphuric acid leads to the formation of traces of nitric acid). If the diphenylamine coloration is very decided after destroying the nitrite, the presence of *nitrate* may be assumed.

Separation of the Sulphur Acids.

Alkali sulphites, hydrosulphites, sulphides and polysulphides in weak alkaline solution decolorise aqueous solutions of magenta and of malachite green, or, better, a mixture of three volumes of 0·25 per cent. magenta solution and one volume of a 0·25 per cent. malachite green solution. The colour returns on addition of formaldehyde or acetaldehyde.

Bisulphides, thiosulphates and thionates do not decolorise the above dyestuff solution.

Carbon dioxide is passed into the solution until a drop gives practically no red colour with phenolphthalein. A portion of the solution is tested for *sulphide* with sodium nitroprusside. If present, it is removed by shaking with an excess of cadmium carbonate and filtering. A portion of the filtrate is then tested with the above dyestuff solution, when decolorisation indicates the presence of a *sulphite*; a further portion of the filtrate is acidified with dilute hydrochloric acid and boiled, when a precipitation of sulphur indicates the presence of a *thiosulphate*.

An alternative method is based on the solubility of barium *thiosulphate* and the insolubility of the *sulphate* and *sulphite*, the latter being identified by the addition of bromine water to the hydrochloric acid extract.

Sulphite and Carbonate.

The precipitation of barium sulphite prevents the direct detection of carbon dioxide by baryta water. The apparatus used for detection of traces of carbonate may be used for detection of carbonate in presence of sulphite, provided an extra wash-bottle containing a solution of potassium dichromate and dilute sulphuric acid (to remove sulphur dioxide) be interposed between the two boiling tubes.

Chromate and Dichromate.

An excess of barium chloride solution is added to precipitate barium chromate; an acid filtrate indicates a *dichromate*.

The dichromate may be precipitated by addition of methylene blue; further precipitate on addition of several drops of dilute sulphuric acid to the filtrate containing an excess of methylene blue indicates presence of a *chromate*.

II. Metallic Radicals (Cations).

PRELIMINARY TREATMENT OF SUBSTANCE IN PRESENCE OF PHOSPHATE, BORATE, SILICATE, FLUORIDE, OXALATE, Etc.

The presence of phosphate, borate, silicate, fluoride, and cyanide, and also of certain organic acids, *e.g.*, oxalic,

tartaric and citric acids, interferes with the group tests, and hence these acids may be removed before proceeding to Group III (except cyanides, which are removed before commencing the group tests), as follows :

Silicate. The substance is evaporated with concentrated hydrochloric acid, and finally heated in an air oven to 150°C. to render the silica insoluble. The residue is then extracted with dilute hydrochloric acid.

Phosphate is removed from Group III precipitate by one of the following methods :

(1) The precipitate is boiled with caustic soda, and filtered. Ammonium chloride is added to the filtrate, which is then boiled. White precipitate indicates *aluminium.* The precipitate is washed and dissolved in the smallest possible amount of dilute hydrochloric acid, ammonium carbonate added to the cold solution until it becomes turbid, and very dilute hydrochloric acid added drop by drop until it becomes clear. An equal volume of ammonium acetate solution is added, and then ferric chloride drop by drop until a reddish liquid is obtained. The solution is boiled for several minutes and filtered.

The precipitate is examined for *aluminium* and *chromium* by the usual Group III separation. The filtrate is boiled with ammonia and ammonium chloride, filtered, any precipitate obtained examined for *chromium*, and the filtrate added to that for Group IV.

The original substance is examined for *iron* as suggested in Group III separation table

(2) The filtrate from Group II, after removal of sulphuretted hydrogen, is evaporated to dryness three times with 10 cc. of concentrated nitric acid to remove hydrochloric acid, dissolved in 10 cc. of nitric acid and 1 grm. pure tinfoil added. When the action has ceased, the mixture is poured into 100 cc. of cold water and allowed to stand over-night. The clear liquid is siphoned off, and used for Group III.

Fluoride and *cyanide* are removed by evaporating substance with concentrated sulphuric acid in a platinum capsule.

Oxalate, tartrate, and other non-volatile organic substances are destroyed by igniting the substance in a platinum capsule, extracting the carbonates formed by means of concentrated hydrochloric acid, moistening the residue with concentrated ammonium nitrate solution, and then continuing to heat until all carbonaceous matter has burnt off, any insoluble residue being fused with potassium bisulphate.

THE SEPARATION OF THE GROUPS.

(N.B.—The colours of the precipitates formed are only indications of the nature of the radicals present, as the presence of one metallic radical may cause the masking of the colour of the precipitate given by another metallic radical.)

I. Acidify with HCl. II. Pass H₂S into soln.

Group I.	Group II.	Group IIA.	Group III.	Group IV.	Group V.	Group VI.
White ppt. LEAD. SILVER, or MERCUROUS	Warm precipitate with ammonium sulphide — Residue. (1) Soluble in HNO₃: Yellow ppt. CADMIUM; Black ppt. BISMUTH, COPPER, or LEAD. (2) Insol. in HNO₃: Black ppt. Sol. in HCl + KClO₃ MERCURIC	Filtrate. On acidifying with HCl: Orange ppt. ANTIMONY; Brown ppt. STANNOUS; Yellow ppt. STANNIC; Bright yellow ppt. ARSENIC	Oxidise soln. with bromine water. Eliminate phosphates, etc. III. Add NH₄Cl and NH₄OH. Brown ppt. IRON; Violet or green ppt. CHROMIUM; White ppt. ALUMINIUM	IV. Pass H₂S into soln. Ppt. (1) Sol. in HCl. White ppt., frequently discolored, ZINC; Pink ppt. MANGANESE. (2) Insol. in HCl, sol. in conc. HCl + KClO₃ Black ppt. COBALT or NICKEL	V. Add ammonium carbonate to filtrate. White ppt. CALCIUM, STRONTIUM, or BARIUM	VI. Add sodium phosphate to soln. White ppt. MAGNESIUM. In original substance: SODIUM and POTASSIUM by flame tests. AMMONIUM by NaOH

Test for Ammonium Salts.

An excess of caustic soda is added, and the solution warmed. Evolution of ammonia indicates presence of an ammonium salt.

Group I

In presence of an arsenate, chromate, dichromate, manganate, or permanganate, reduce with sulphur dioxide, and boil off the excess. Acidify solution with hydrochloric acid.*

Filter and reserve *filtrate* for Group II.

Extract white *precipitate* with hot water, and filter hot.

RESIDUE.
Wash with hot water until filtrate gives no ppt. with silver nitrate soln. Treat residue with ammonia, and filter immediately.

FILTRATE.
White crystals may separate on cooling. Add potassium chromate and sodium acetate to soln. Yellow ppt., soluble in caustic soda :
LEAD.

RESIDUE.
Wash, and dissolve in dilute hydrochloric acid to which has been added a crystal of potassium chlorate, and almost neutralise with caustic soda. Boil with a piece of copper foil. Metallic deposit, gives mirror of globules of mercury on heating in an ignition tube :
MERCURY(-OUS).

FILTRATE.
Acidify with nitric acid. White curdy ppt., filter, residue soluble in sodium thiosulphate soln., the soln. darkening on heating :
SILVER.

* White ppt., sol. in excess, indicates bismuth or antimony, or the presence of aluminate, stannate, antimonate or zincate. Ppt. of sulphur indicates presence of a thiosulphate or polysulphide Gelatinous ppt. indicates an alkali silicate. Amorphous ppt., white when cold and yellow hot, indicates an alkali tungstate. White ppt., soluble in hot water, will be obtained in presence of much borate. Complex cyanides give a ppt. of an insoluble simple cyanide.

Evaporate to dryness and use hydrochloric acid extract for Group II.

Group II.

Warm *filtrate* from Group I, pass in a slow current of hydrogen sulphide, filter, dilute somewhat, and pass hydrogen sulphide into the warm filtrate. Filter, if necessary, through same filter paper, and reserve *filtrate* for Group III. Light yellow precipitate of sulphur indicates presence of an

oxidising agent (ferric salt, hydrogen peroxide, etc.). **Wash precipitate with fresh hydrogen sulphide solution, rejecting filtrate, and then warm with 5 cc. of yellow ammonium sulphide.** Filter, and reserve *filtrate* for Group IIa.

Wash residue with water containing ammonium sulphide, and then with fresh hydrogen sulphide solution, rejecting filtrates. Digest the precipitate in an evaporating basin with 5 cc. of nitric acid (1 :1). Dilute somewhat, and filter.

RESIDUE.
Pierce the filter-paper, and wash ppt. into an evaporating dish with 1 cc. of water and then with 5 cc. of warm, dilute hydrochloric acid to which has been added a crystal of potassium chlorate. Evaporate to 2 cc., filter if necessary, and add stannous chloride solution to the filtrate. White or grey ppt. :
MERCURY(-IC).

FILTRATE.
Evaporate to 2-5 cc. in an evaporating dish, add 5 cc. dilute sulphuric acid, and evaporate almost to dryness. Stir residue with 5 cc. of cold dilute sulphuric acid, and filter.

White ppt.
Soluble in ammonium acetate solution, reprecipitated on addition of sulphuric acid :
LEAD.

Filtrate.
Add a slight excess of ammonia, and filter.

White ppt.
Solution in hydrochloric acid gives on addition of water a white ppt. :
BISMUTH.

Blue filtrate :
COPPER.
In presence of copper, acidify with dilute sulphuric acid, and boil with iron wire. Filter rapidly from precipitated copper, etc. Pass hydrogen sulphide into filtrate. Yellow ppt. :
CADMIUM.

Note.—Traces of copper are best detected by evaporating some of the *original* substance almost to dryness with dilute sulphuric acid, filtering if necessary, and then adding 1 cc. of a dilute solution of titanous sulphate to the filtrate. Pink opalescence or precipitate of metal indicates presence of copper. (Black precipitates are obtained in presence of arsenic or platinum ; a purple solution is obtained in presence of gold.)

Group IIa.

Dilute *filtrate*, obtained by warming precipitate with ammonium sulphide in Group II, with an equal volume of water, and acidify with dilute hydrochloric acid. Boil, allow precipitate to settle, and decant off as much liquid as possible. Filter and wash the precipitate, rejecting the filtrate.

Warm the precipitate, which contains sulphur, with ammonium carbonate solution, adding solid ammonium carbonate if necessary, and filter.

RESIDUE.

Boil with concentrated hydrochloric acid. If necessary filter from sulphur after dilution. Concentrate to a very small volume, and place several drops of liquid on a piece of suitably bent platinum foil, on which is a fragment of zinc foil. After some seconds remove the zinc.

Black stain on platinum foil, insoluble in hydrochloric acid, but soluble in ammonium sulphide, the solution leaving an orange residue on evaporation :
ANTIMONY.

Place zinc and platinum foil in test-tube with remainder of liquid, and after hydrogen has been evolved rapidly for a short time, filter if necessary, and add mercuric chloride solution to filtrate. White or grey ppt. :
TIN.

FILTRATE.

Acidify with hydrochloric acid, filter, and wash ppt. Pierce filter-paper, wash ppt. into an evaporating dish, and dissolve in concentrated nitric acid. Evaporate almost to dryness, add sulphur dioxide solution and then 5 cc. of cold dilute hydrochloric acid, and a piece of copper foil, and warm. Metallic deposit (*Reinsch s test*), gives white sublimate on heating in ignition tube :
ARSENIC.

(An alternative method is to dissolve the ppt. of arsenic sulphide by warming with hydrogen peroxide and ammonia. Boil, and add ammonium chloride and magnesium chloride. White crystalline ppt. indicates *arsenic*).

Marsh's Test. Traces of *arsenic* and *antimony* are detected by pouring into a hydrogen generator the solution obtained by evaporating the nitric acid solution just to dryness and dissolving in cold hydrochloric acid. The arsenic and antimony hydrides burn with the hydrogen. The production of a brown stain, soluble in hypochlorite, on a cold porcelain crucible lid held in the flame, indicates the presence of *arsenic*. In case the stain does not dissolve readily in hypochlorite, it indicates the presence of *antimony*. (Nitrates, chlorates, etc , must be absent in this test.)

An alternative method of detecting *antimony* or *tin* in the residue is as follows : Boil the solution in hydrochloric acid with iron wire for several minutes, filter off precipitated antimony, etc., and add mercuric chloride to filtrate to test for *tin*. Dissolve residue in hydrochloric acid (1 : 1) containing a small crystal of potassium chlorate, boil, dilute somewhat, and pass in hydrogen sulphide. Orange precipitate indicates presence of *antimony*.

Group III.

Phosphates, etc., must be removed before proceeding to Group III.

Oxidise *filtrate* from Group II with bromine water, boil off the excess, and add a few cc. of ammonium chloride and an excess of ammonia.

Filter immediately, and reserve *filtrate* for Group IV. Wash precipitate, pierce the filter-paper, and wash precipitate into a boiling tube. Add sodium peroxide in small amounts, boil for two or three minutes, allow to cool, dilute somewhat, and filter.

RESIDUE.
Dissolve in dilute hydrochloric acid, and add potassium ferrocyanide solution.
Blue ppt. :
IRON.

Test original substance in hydrochloric or sulphuric acid solution with :
(a) Potassium ferrocyanide solution :
Blue ppt. : FERRIC.
(b) Potassium ferricyanide solution.
Blue ppt. : FERROUS.

FILTRATE.
Add ammonium sulphate (solid) and filter.

White gelatinous ppt., gives light blue mass on heating with cobalt nitrate on charcoal:
ALUMINIUM.

Yellow filtrate. Boil with excess caustic soda until free from ammonia.
Acidify with acetic acid, and add silver nitrate solution. Red ppt.
CHROMIUM.

Note.—Traces of *iron* may be detected by reducing to the *ferrous* condition with zinc dust (free from iron), filtering, adding citric acid followed by an excess of ammonia, and then *diamethylglyoxime*, which gives a pink colouration with *ferrous* iron.

Group IV.

Add ammonium sulphide to two drops of *filtrate* from Group III. In case a precipitate is obtained, warm remainder of *filtrate*, and pass a current of hydrogen sulphide, filter, and reserve *filtrate* for Group V. Wash precipitate several times with water containing ammonium sulphide and then with cold dilute hydrochloric acid.

RESIDUE

Test by borax bead for
COBALT and NICKEL

As the presence of a small amount of cobalt will mask the presence of even large amounts of nickel in the borax bead, pierce filter-paper, and dissolve ppt. in hydrochloric acid to which has been added a crystal of potassium chlorate. Evaporate almost to dryness. Dissolve the residue in 5 cc. of water, add an equal volume of ammonium chloride soln., and several drops of ammonia.

. Divide soln. into two portions :
To one portion add 1 cc. of a soln. of the sodium salt of *α*-benzildioxime (or an alcoholic soln. of *α*-dimethylglyoxime). Pink ppt. :
NICKEL.

To the other portion add 1 cc. of a soln. of the sodium salt of *α*-nitroso-*β*-naphthol. Orange coloration, or ppt., not destroyed by just acidifying with dilute sulphuric acid :
COBALT.

FILTRATE.

Boil with an equal volume of caustic soda solution. Filter.

RESIDUE.
Test by borax bead for MANGANESE. Confirm by converting into permanganate by digesting with potassium persulphate and a few drops of silver nitrate.

FILTRATE.
Acidify with acetic acid and pass in hydrogen sulphide. White ppt., becomes green on heating with cobalt nitrate on charcoal :
ZINC.

(*Note.*—Traces of *nickel* in cobalt salts may be detected by adding concentrated ammonia soln., oxidising with hydrogen peroxide, boiling to destroy the excess, and then adding the nickel reagent. After filtering, the residue is washed with hot water. Pink residue indicates presence of *nickel*).

Group V.

If *filtrate* from Group IV is brown, due to presence of nickel, acidify with acetic acid, warm, and filter.

In case solution is not quite clear, add bromine water to oxidise suspended sulphur, and boil off the excess. (This is to be avoided if possible as it may cause the precipitation of traces of barium sulphate, etc.)

Concentrate the solution to 5 cc., and to the clear solution add an excess of ammonia and then ammonium carbonate, warm to about 60–70°C., filter, and reserve *filtrate* for Group VI.

Wash residue with water, and then treat with dilute nitric

acid, collecting filtrate in an evaporating basin. Evaporate filtrate *just* to dryness.

(1) Dissolve a *small portion* of residue in water, and add calcium sulphate solution :—

No ppt. even on standing.	Calcium may be present. Barium and strontium absent.
Gradual formation of ppt.	Strontium present; possibly also calcium. Barium absent.
Immediate ppt.	Barium present; possibly also strontium and calcium.

Calcium may be confirmed by freeing *another* small portion of residue from barium and strontium, if present, by adding dilute sulphuric acid to the solution in water, allowing to stand for several minutes, filtering, and then adding ammonia and ammonium oxalate to the filtrate. White ppt. indicates *calcium.*

(2) In case addition of calcium sulphate produces a precipitate, the remainder of the residue is stirred with three or four portions of 2-3 cc. of alcohol (95 per cent.), decanting the alcohol through a filter-paper moistened with alcohol.

RESIDUE.	FILTRATE.
Dry, add 3 cc. concentrated hydrochloric acid, and evaporate to dryness; repeat addition and evaporation. Treat dry residue several times with alcohol (95 per cent.). Filter.	Evaporate portion to dryness, and examine by flame coloration for CALCIUM. To remainder add ammonia and ammonium oxalate. White ppt. : CALCIUM.

RESIDUE.	FILTRATE.
Examine by flame coloration for BARIUM. Dissolve in water, and add potassium dichromate and sodium acetate. Yellow ppt. : BARIUM.	Evaporate to dryness, and examine residue by flame coloration for STRONTIUM.

Group VI.

(**1**) To approximately half of the *filtrate* from Group V add a small amount of ammonia, and ammonium chloride, if necessary, to dissolve any precipitate formed. Add sodium phosphate and a few cc. of concentrated ammonia solution. Allow to stand for some time if precipitate is not formed immediately.

White crystalline ppt. MAGNESIUM.

(**2**) Evaporate a small portion of the *filtrate* from Group V to dryness, and examine by flame coloration for POTASSIUM, SODIUM, and LITHIUM. Confirm by testing *original* substance.

(**3**) Evaporate the remainder of the solution to dryness in a porcelain or platinum dish and gently ignite the residue to expel ammonium salts. Dissolve the residue in a small amount of water, disregarding any residue of basic magnesium salt, and add barium hydroxide solution until strongly alkaline. Heat to boiling, filter, make the filtrate just acid with hydrochloric acid, and precipitate the barium with ammonia and ammonium carbonate. Filter, evaporate the filtrate to dryness, heat the residue gently to expel ammonium salts, take up with water, and repeat the precipitation with ammonium carbonate, filter, evaporate to dryness and remove ammonium salts. Dissolve the residue in a small amount of water, filter and evaporate the filtrate to dryness. (None of these operations should be performed in glass owing to the danger of extracting alkalis.) Add to the residue 10 cc. of 2N perchloric acid, and evaporate carefully until dense fumes of perchloric acid are evolved. Cool and add 20 cc. of alcohol. (If the perchloric acid-ammonia solution be heated there is extreme danger of a violent explosion). If necessary, add 2–3 cc. more perchloric acid, stir gently, and filter. Wash the ppt. with alcohol. Pass dry hydrochloric acid gas through the alcoholic filtrate to saturation, filter off the precipitated sodium chloride, wash with alcohol, and dissolve the residue in 1 cc. water. Add 2 cc. potassium pyroantimonate solution, and allow to stand over-night. A *crystalline* ppt. indicates sodium.

(The pyroantimonate solution is prepared by treating 20 grms. of the commercial salt with a litre of boiling water, boiling till nearly all the salt has dissolved, cooling quickly, adding 30 cc. KOH and filtering.)

Examine *original* substance for potassium as follows :

Boil with a solution of sodium carbonate (free from potassium) until free from ammonium salts, filter, add a

slight excess of acetic acid to the filtrate and then a recently prepared one per cent. solution of sodium cobaltinitrite.

Yellow ppt.   POTASSIUM.

An alternative method is to add a strong solution of sodium acetate, and then tartaric acid. White crystalline precipitate, best obtained by shaking in presence of alcohol, indicates POTASSIUM.

Notes on the Group Separations.

In order that arsenates, chromates, etc., should be precipitated in the course of the groups, it is essential to reduce with sulphur dioxide to arsenites, chromic salts, etc. ; otherwise chromate might give a green precipitate in Group II, and arsenic would only be precipitated, together with much sulphur, after a slow reduction with hydrogen sulphide. As this leads to the production of sulphuric acid in the solution, and hence would cause the precipitation of the insoluble sulphates of lead, barium, etc., this method of treatment must be avoided in presence of these metals. In such cases chromate is reduced by boiling with hydrochloric acid and alcohol, and arsenate by hydrogen sulphide, taking great care to ensure its complete reduction and removal (see notes on Group II).

Group I.

Silver chloride dissolves in ammonia to form the complex salt : $[Ag(NH_3)_2]Cl$, whereas mercurous chloride gives the insoluble compound $Hg(NH_2)Cl$ mixed with metallic mercury.

Owing to the slight reducing action of mercurous chloride in presence of ammonia, a small quantity of silver might not be detected in presence of large amounts of mercurous chloride, as it would remain insoluble as metallic silver. This may be prevented by oxidising the mixture of the two chlorides with bromine water, when only the silver chloride remains undissolved. Mercury is detected in the filtrate by means of stannous chloride.

The solubility of silver chloride in sodium thiosulphate depends upon the formation of a complex ion :

$$2AgCl + 3Na_2S_2O_3 = Na_4[Ag_2(S_2O_3)_3] + 2NaCl.$$
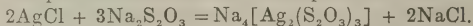
On warming in presence of an excess of thiosulphate, the black silver sulphide is produced.

Group II.

Care must be taken not to have the solution too strongly acid, as this prevents the precipitation of cadmium sulphide. On the other hand, the solution must contain a moderate

amount of hydrochloric acid, to prevent the formation of a colloidal suspension of arsenic sulphide, and to keep bismuth and antimony in solution. It has been found that arsenic is most readily precipitated if the concentration of hydrochloric acid is above 2N, whereas the concentration of the acid must be below N/2 to obtain complete precipitation of other members of this group, notably cadmium, antimony, and tin. To prevent metals of later groups from being precipitated, the concentration of acid must be above N/8.

On passing hydrogen sulphide into the solution, mercuric salts may give a white precipitate of a chlorsulphide which passes through yellow and brown to black, and lead salts frequently give a reddish precipitate of chlorsulphide which becomes black on warming and further saturating with hydrogen sulphide.

As copper sulphide is somewhat soluble in yellow ammonium sulphide, the titanous sulphate test must be carried out with the *original* substance (in absence of nitric acid), unless sodium sulphide is used, in which the copper sulphide is not soluble.

An alternative delicate test for copper is given by the precipitation of its ferrocyanide in acetic acid solution.

Group IIa.

Yellow "ammonium sulphide" contains polysulphides, thiosulphate, etc.

The solubility of the sulphides of this group in ammonium sulphide is due to the formation of the salts of complex thio-acids, *e.g.*, ammonium thioarsenite, $As(SNH_4)_3$. The solution should not be boiled as it is liable to lead to the precipitation of the red oxysulphide of antimony (Sb_2S_2O) by oxidation of the thioantimonite $Sb(SNH_4)_3$. In case yellow ammonium sulphide is used, ammonium thioantimonate is produced:

$$Sb_2S_3 + 2(NH_4)_2S_2 = SbS(SNH_4)_3 + SbS_3NH_4.$$
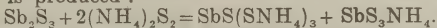
Stannous sulphide is not soluble in colourless ammonium sulphide, but is converted into the soluble stannic compound by yellow ammonium sulphide. On this account it is necessary to test in the *original* substance for the condition of the tin as follows:

A solution is prepared in the cold containing hydrochloric acid. Mercuric chloride is added, when white or grey precipitate indicates presence of a *stannous* compound; in case no precipitate is obtained, the presence of a *stannic* compound may be assumed.

The metallic deposit obtained on the copper foil is probably an arsenide, Cu_5As_2.

Group III.

Before adding the group reagent, it is necessary to oxidise any ferrous salt present, which may have been produced from a ferric salt by hydrogen sulphide. It follows that the tests for ferrous and ferric ions must be carried out with the *original* substance. Fresh solutions of potassium ferro-cyanide and ferricyanide should be used, as these solutions decompose on standing. In case iron has been found to be present, but neither of these reagents gives any reaction, the presence of the iron as ferrocyanide or ferricyanide may be suspected.

Before oxidising, as much hydrogen sulphide as possible should be removed by boiling, to avoid its oxidation to sulphuric acid, which might cause the precipitation of barium, etc. In case the solution is not quite clear after boiling with an excess of bromine water, it is filtered, and the residue examined by flame coloration (as suggested for barium sulphate, see " Dry-way tests ").

It is essential to free completely from bromine, as otherwise a hydrated manganese oxide will be precipitated on addition of ammonia. In presence of much nitric acid (hence the advantage of using bromine water), or even on exposure of the warm ammonia solution to air, manganese may be precipitated as a brown powder, readily distinguished by its character from ferric hydroxide.

The addition of ammonium chloride is necessary to keep magnesium, etc., in solution, and also to render the precipi-tation of aluminium hydroxide more complete (probably due to the conversion of the colloidal solution (*aqua sol*) of aluminium hydroxide into the insoluble *gel*). Even in presence of ammonium chloride, it is essential to boil for several minutes to complete the precipitation of chromium.

On boiling with sodium peroxide, chromium hydroxide is oxidised to chromate, and the aluminium hydroxide dissolves in the caustic soda formed to give sodium aluminate. Addition of ammonium sulphate to the filtrate frees the solution from caustic alkali, forming ammonia, in which the aluminium hydroxide is not soluble.

As caustic soda frequently contains aluminate and silicate, it is advisable to carry out a " blank " on the caustic soda solution in case only traces of aluminium are found. A confirmatory test for aluminium is as follows : To about 5 cc. of the neutral or acid solution under examination is added

1 cc. of a filtered solution of Alizarin S, and then ammonia until the solution is alkaline, as shown by the purple colour. The solution is boiled for a few moments, allowed to cool, and then acidified with dilute acetic acid, when a red coloration or precipitate remaining is conclusive evidence of the presence of aluminium (see Atack, *J. Soc. Chem. Ind.*, Sept. 1915).

The necessity for removing phosphate is due to the phosphates of certain metals of later groups being soluble in hydrochloric acid, but being reprecipitated on addition of ammonia. Hence they would appear in Group III, *e.g.*, calcium phosphate might be mistaken for the aluminium hydroxide precipitate.

For similar reasons fluorides must be removed before proceeding to Group III; for example, precipitated calcium fluoride is soluble in hydrochloric acid, but would be reprecipitated on addition of ammonia. As is also the case with borates, fluorides would only be precipitated incompletely in Group III, and metals present as borates or fluorides may frequently be identified as usual in the later groups.

The method of separating phosphate as a basic tin phosphate before proceeding to Group III is more satisfactory than separating as basic ferric phosphate in presence of chromium, but manganese is carried down with the precipitate, which is often difficult to filter.

The removal of organic acids before Group III is necessary owing to their tendency to form complex ions with ferric, aluminium, etc., salts which do not give a precipitate with ammonia. Thus aluminium hydroxide is soluble in neutral tartrates, forming a compound containing a complex negative ion.

Oxalates must be removed, as addition of ammonia would precipitate calcium, strontium and barium as oxalates in Group III.

As ammonium carbonate is frequently present in the ammonia, traces of Group V metals may be carried down in this group; in such a case, dissolve the precipitate in dilute hydrochloric acid, and re-precipitate by adding ammonia drop by drop. The ammonia should also be tested for sulphate, which would precipitate metals of Group V.

Note.—In presence of large amounts of cobalt, or if small amounts of zinc are to be detected, it is necessary to precipitate the metals of Groups III and IV together, by

adding ammonia and ammonium chloride and then passing in hydrogen sulphide, filtering, and washing with water containing ammonium sulphide.

Cobalt and nickel are obtained as sulphides insoluble in cold 10 per cent. hydrochloric acid, whereas the remainder of the precipitate is soluble. The filtrate is then oxidised with bromine, and iron, chromium, and aluminium hydroxides precipitated by almost neutralising with sodium carbonate, adding precipitated barium carbonate and then allowing to stand, with occasional shaking, for one hour. The precipitate is filtered off, and examined as in the usual Group III separation. The solution contains manganese, zinc, and traces of barium (from the barium carbonate), and is examined for manganese and zinc as Group IV separation.

A disadvantage of this joint method of precipitation is that phosphates of the metals of later groups may be precipitated, and cause difficulties in the separation. Phosphates of the metals of Group IV will have been converted into sulphides by digesting with ammonium sulphide.

Group IV.

It is advisable to use hydrogen sulphide in this group, as ammonium sulphide frequently contains sulphate, which would cause the precipitation of barium, etc. The use of hydrogen sulphide further avoids the dissolution of nickel sulphide, which is not soluble in colourless ammonium sulphide.

In presence of much ammonia, it is necessary to boil for some time to effect complete precipitation of the manganese sulphide.

Although nickel and cobalt sulphides are insoluble in dilute hydrochloric acid, they are not precipitated in Group II. This behaviour is ascribed to a change in the state of aggregation of these sulphides immediately after precipitation.

As cobalt and nickel sulphides oxidise rapidly to the soluble sulphates, it is necessary to wash with water containing ammonium sulphide, and to avoid exposing the precipitate to air. Traces of nickel generally pass into the solution with the zinc and manganese.

As manganese sulphide is soluble in acetic acid, zinc and manganese may be separated in this manner.

Group V.

As a fresh solution of ammonium *carbonate* contains *bicarbonate* and *carbamate*, it is advisable to warm to 60-70°C. (but not above this temperature) to ensure the hydration of the carbamate :

$$CO\begin{matrix} \diagup NH_2 \\ \diagdown ONH_4 \end{matrix} + H_2O = CO\begin{matrix} \diagup ONH_4 \\ \diagdown ONH_4 \end{matrix}$$
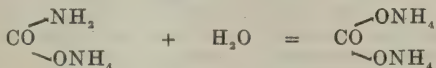
and decomposition of the bicarbonate.

As the reaction :

$$CaCl_2 + (NH_4)_2CO_3 = 2NH_4Cl + CaCO_3$$
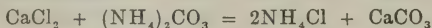
is reversible, it is essential to use a large excess of ammonium carbonate and to warm only until the precipitate has become crystalline. In presence of much ammonium chloride, which is essential if magnesium is present, the precipitation of small amounts of calcium is incomplete, or may not take place at all. In case the presence of calcium has been indicated by the flame coloration test, but no precipitate is obtained with ammonium carbonate, a portion of the solution should be warmed and treated with ammonium oxalate, and any precipitate obtained examined for calcium by the flame coloration test.

Magnesium is frequently carried down in this group, and a careful reprecipitation must be carried out if traces of magnesium are to be detected in Group VI.

Group VI.

In case the separation of aluminium, calcium, barium, etc., has not been complete, a *flocculent* precipitate may be obtained on addition of sodium phosphate. These metals may be removed completely from the filtrate from Group V by adding a large amount of ammonium chloride, and then ammonium sulphate and oxalate, and boiling for several minutes. On addition of sodium phosphate to the filtrate, the production of a *crystalline* precipitate indicates the presence of magnesium.

As traces of sodium and potassium salts will probably have been introduced with the group reagents, it is essential to confirm in the *original* substance, although it is to be remembered that other elements may be present in this which will mask the potassium flame coloration.

EXAMINATION OF INSOLUBLE SUBSTANCES.

The substances which are insoluble or practically insoluble in single mineral acids, but are soluble in *aqua regia*, are : mercuric sulphide, antimony oxide, stannic sulphide, sulphur, and, after continued treatment, Prussian blue.

The substances which are insoluble or practically insoluble in mineral acids, including *aqua regia*, are : silver chloride, bromide, iodide and cyanide; sulphates of barium, strontium and lead; calcium fluoride; fused lead chromate; fused chromic oxide and chrome iron ore; stannic and titanic oxide ores; alumina; silica and many silicates; carbon; and carborundum. In addition, insoluble substances may contain combined phosphate, borate, sulphate, chloride or fluoride, which will not be found by the usual tests.

The general method of treatment is to fuse with fusion mixture, and extract the melt with hot water, and then with dilute acids.

Ignited ferric oxide, chromic oxide, and alumina, are very difficult to dissolve in acids, and are best fused with potassium bisulphate, or with acid potassium fluoride, a method of treatment which is the most satisfactory for the solution of many minerals.

Platinum vessels are attacked by easily reducible metals, such as lead, silver, and bismuth, and also by caustic alkalies. If porcelain vessels are used for the fusion, silica, alumina, etc., will be introduced. Consequently in presence of lead, etc., the acid fluoride method is used.

In case the insoluble substance has not already been examined by the dry-way tests, these tests should be carried out, as they generally give an indication of the substance under examination. According to the results obtained, one of the following methods is attempted for effecting solution if necessary for complete identification.

(1) Insoluble silver halides are dissolved by a solution of sodium thiosulphate, the solution darkening on heating. For complete identification, they are reduced in contact with zinc and dilute sulphuric acid to metallic silver. After filtering, the filtrate is tested for the halogen acid; the residue is dissolved in dilute nitric acid, and hydrochloric acid added to test for silver.

(2) Insoluble barium, strontium, and calcium sulphates, silica and silicates should be fused with five times the amount of fusion mixture on platinum foil for several minutes, and the mass plunged into water whilst still hot.

After crushing with a glass rod and heating to the boiling-point, the liquid is filtered, and the residue washed with hot water and then treated with dilute hydrochloric acid. The aqueous and acid extracts are then examined for acid and metallic radicals respectively. The formation of a gelatinous precipitate on acidifying the aqueous solution indicates silica or silicate.

Sodium and potassium are detected in silicates after fusing with ammonium fluoride.

Silicon and ferro-silicon are dissolved by fusing with caustic soda.

An alternative method for insoluble sulphates is to confirm the sulphate by boiling with concentrated sodium carbonate solution, extract the residue with hydrochloric acid, and examine the solution for metallic radicals.

(3) Stannic and titanic oxide ores may be brought into solution by fusing with caustic soda in a silver or nickel dish. In the case of chrome iron ore, sodium peroxide should be added. The melt is extracted with water and the residue dissolved in hydrochloric acid.

Tin ores may be brought into solution by reducing to a fine powder, moistening with commercial hypophosphorous acid, and heating to dryness at a temperature not exceeding 240°C. The residue is extracted with hydrochloric acid, and tested for tin.

(4) Calcium fluoride may be identified by fusing with potassium bisulphate on platinum foil, and subsequently examining by the flame test.

(5) Insoluble complex cyanides are decomposed readily by digesting with caustic soda solution in a porcelain dish.

EXAMINATION OF AN ALLOY.

As certain electronegative elements (*e.g.* carbon, silicon, phosphorus, and sulphur) are frequently present in small quantities, it is inadvisable to attempt to dissolve an alloy in hydrochloric acid, as volatile hydrides would be formed from carbides, silicides, phosphides, sulphides and arsenides, forms in which these electronegative elements are frequently present. It is hence convenient to dissolve in an oxidising agent, such as nitric acid. In the case of the ferro-alloys, a powdered sample may be fused with potassium bisulphate and persulphate.

Warm fragments of alloy with nitric acid (1 : 1). Dilute with twice the volume of water. A dark-coloured solution indicates the presence of *carbon*. Filter. If completely dissolved indicates absence of *tin* and *antimony*

FILTRATE A.
After addition of Filtrates B and C, examine by group tests for metals, and also for sulphate, phosphate, and arsenate, the presence of which indicates the presence of the corresponding element in the alloy.

RESIDUE
(may contain tin, antimony, and bismuth, with traces of other metals; also phosphate).
Pierce filter-paper, and wash precipitate into a test-tube. Add a small piece of caustic potash, and then 10 cc. of concentrated sodium sulphide solution, digest on a water-bath for 15 minutes, dilute and filter.

FILTRATE.
(may contain tin antimony or phosphate).
Acidify with dilute hydrochloric acid and filter.

RESIDUE.
Extract with hot dilute nitric acid.

FILTRATE B.
Add to Filtrate A.

RESIDUE.
Wash, dry, and fuse with caustic potash in a silver dish. Rinse into porcelain dish with hot water and extract with dilute nitric acid. Filter.

FILTRATE.
Test by ammonium molybdate for phosphate, the presence of which indicates PHOSPHORUS.

RESIDUE.
Examine for TIN and ANTIMONY (Group IIa).

FILTRATE C.
Add to Filtrate A.

Gelatinous residue indicates the presence of SILICON

REACTIONS OF CERTAIN OF THE "RARER" METALS.

After dissolving the powdered substance by fusion with potassium bisulphate, with the addition of persulphate if necessary, and subsequently extracting with cold water and then with concentrated hydrochloric acid, the liquid is diluted and filtered. Any residue may then be dissolved by fusing with caustic soda and sodium peroxide in a nickel crucible, extracting with hot water, afterwards boiling the solution to destroy the last traces of sodium peroxide. The solution is acidified with hydrochloric acid; the formation of a precipitate indicates the presence of tungsten or silicon.

Preliminary test. A small piece of zinc is introduced into a portion of the hydrochloric acid solution. After a brisk evolution of hydrogen has occurred for one minute, the liquid is decanted off the zinc, and, when quite free from undissolved zinc particles, two drops of a very dilute solution $(N/1000)$ of methylene blue are added. The blue colour is destroyed in presence of traces of titanium, vanadium, molybdenum, and tungsten. In case the colour of the methylene blue persists, it may be taken as final evidence of the absence of these metals from the solution.

Group I.

Tungsten.

The behaviour of a solution of an alkali tungstate is as follows :

(1) Mineral acids give a white precipitate which becomes yellow on heating. The white precipitate is soluble in phosphoric acid and in alkalies.

(2) Hydrogen sulphide does not give a precipitate in acid solution; but, on addition of ammonium sulphide and then an acid, a light brown precipitate soluble in ammonium sulphide is obtained.

(3) Reducing agents give a blue solution.

(4) Lead and mercurous tungstates are formed as white insoluble precipitates.

Separation from Silicic Acid :

Tungstic acid only is soluble in ammonium carbonate.

Separation from Titanium:

Tungstic acid only is insoluble in dilute sulphuric acid,

Group IIa.

Note.—Although gold and platinum may be considered to belong to this Group, owing to the comparative difficulty with which their sulphides dissolve in yellow ammonium sulphide they are generally removed before proceeding to Group II. On heating with oxalic acid, gold is precipitated as such, and the platinum may be removed from the filtrate by evaporating with ammonium chloride to obtain the insoluble ammonium platinic chloride, and extracting the residue with alcohol (75 per cent.). The solution, freed from alcohol, is then used for Group II.

Cold.

The behaviour of a solution of chlorauric acid is as follows :

(1) With cold solutions containing gold, hydrogen sulphide gives a black precipitate of the disulphide, soluble with difficulty in yellow ammonium sulphide, but more soluble in yellow potassium sulphide. At the boil, hydrogen sulphide gives a brown precipitate of metallic gold, soluble in alkali polysulphides.

(2) Ferrous salts and oxalic acid reduce acid solutions giving a brown precipitate of gold. (*Compare* platinum.)

(3) Stannous chloride gives a brown precipitate with strongly acid solutions, and a purple solution or precipitate with faintly acid solutions (also given by titanous chloride).

(4) Hydrogen peroxide precipitates finely divided gold from alkaline solutions.

Platinum.

The behaviour of a solution of chlorplatinic acid is as follows :

(1) Hydrogen sulphide gives a dark-brown precipitate with hot solutions, soluble with difficulty in alkali polysulphides.

(2) Ammonium and potassium chloride give yellow, crystalline precipitates with concentrated solutions, or on addition of alcohol in the case of dilute solutions.

(3) Alkali iodides give dark-brown solutions

(4) Neither ferrous salts nor oxalic acid precipitate platinum from acid solutions. (*Compare* gold.)

(5) Stannous chloride gives a blood-red solution, the colour being extracted by ether.

Molybdenum

The behaviour of a solution of an alkali molybdate is as follows :

(1) Hydrogen sulphide gives a blue solution and then a brown precipitate soluble in ammonium sulphide. On oxidation in air or by concentrated nitric acid, the brown sulphide gives glistening needles of molybdic oxide, which is yellow whilst hot.

(2) On heating with several drops of concentrated sulphuric acid in a porcelain dish, and allowing to cool, an intense blue mass is formed.

(3) Reducing agents give a blue solution, which on further reduction with zinc and concentrated hydrochloric acid, becomes successively green, orange, and pink.

(4) Addition of potassium ferrocyanide to a solution containing a mineral acid gives a reddish-brown precipitate soluble in caustic alkalies and in ammonia. (*Compare* uranium.)

Separation from Arsenic, Antimony and Tin :

Fuse Group IIa precipitate with twenty times the amount of a mixture of equal parts of fusion mixture and sodium peroxide in a nickel crucible for ten minutes. Extract the sodium arsenate and molybdate with cold water, filter from the undissolved sodium antimonate and stannic oxide, and wash with caustic soda solution.

Acidify the filtrate with hydrochloric acid, make strongly ammoniacal, and precipitate the arsenate by addition of magnesia mixture. Examine concentrated filtrate for molybdenum.

The residue is dissolved in hydrochloric acid (1 : 1) and examined for antimony and tin as usual.

Group III.

Titanium.

The behaviour of a solution of a titanic salt is as follows :

(1) Ammonia and ammonium sulphide give a white, gelatinous precipitate.

(2) Caustic potash gives a white, gelatinous precipitate, insoluble in excess. (*Compare* aluminium.)

(3) Tin and zinc, but not hydrogen sulphide or sulphur dioxide (*compare* vanadium), reduce acid solutions to violet titanous salts.

(4) With hydrogen peroxide, titanium sulphate gives a colour similar to that of vanadium (3).

(5) Potassium ferrocyanide gives a brown precipitate from slightly acid solutions.

Separation from Iron, Aluminium and Chromium.

Add sodium carbonate to the cold solution (free from organic acids) until a slight precipitate is obtained. After dissolving precipitate in a few drops of sulphuric acid, dilute to a large volume with water, to hydrolyse the sulphate, and boil for half an hour. Filter, and wash the precipitated metatitanic acid with very dilute sulphuric acid. The precipitate dissolves slowly on digesting with concentrated hydrochloric acid.

Uranium.

The behaviour of a yellowish-green solution of a uranyl salt is as follows :

(1) Ammonia and caustic alkalies give a yellow, amorphous precipitate of a uranate, soluble in alkali carbonates, particularly in ammonium carbonate.

(2) Ammonium sulphide gives a brownish-red precipitate, soluble in dilute acids and in ammonium carbonate.

(3) Potassium ferrocyanide yields a brown precipitate, insoluble in mineral acids, which is turned yellow by caustic potash. (*Compare* molybdenum.)

Separation from Iron, Aluminium and Chromium.

Dissolve Group III precipitate in a small amount of dilute hydrochloric acid, make strongly alkaline with caustic soda, boil, dilute with hot water, and boil for several minutes. Filter hot from sodium aluminate solution, wash precipitate thoroughly with hot water. Warm precipitate with ammonium carbonate solution, but do not boil. Filter, and test for uranium in filtrate by acidifying and adding potassium ferrocyanide.

Group IV.
Vanadium.*

The behaviour of a solution of an alkali vanadate is as follows :

(1) Ammonium sulphide gives a red solution which on acidifying with dilute sulphuric acid gives a brown precipitate soluble in alkalies, and alkali carbonates and sulphides.

* Although vanadate solutions do not give a precipitate with ammonium sulphide, which first acts as a reducing agent, it is convenient to consider vanadium in Group IV.

(2) **Hydrogen** sulphide, sulphur dioxide, and **other** reducing agents give blue solutions.

(3) Hydrogen peroxide produces a reddish brown solution, the colour of which is not extracted by ether. (*Compare* chromate.)

(4) Lead and mercurous vanadates are insoluble in water but soluble in nitric acid.

Detection of Vanadium in Ores, etc.

Fuse with five times the weight of a mixture containing four parts of fusion mixture and one part of potassium nitrate. Extract with water and reduce any manganate formed with alcohol. Filter, and almost neutralise filtrate with nitric acid. Evaporate the alkaline solution almost to dryness, add water, and filter. Add mercurous nitrate solution, when any phosphate, arsenate, chromate, molybdate, tungstate, or vanadate present will be precipitated. Boil, filter, and dry precipitate. Ignite, fuse the residue with a small amount of sodium carbonate, and extract with water. Yellow solution indicates *chromium*. Acidify with sulphuric acid, and precipitate *arsenic* and *molybdenum* by means of hydrogen sulphide. Filter, and pass a current of carbon dioxide through filtrate at the boil. Test for *vanadium* in filtrate by Test (3) above.

Group VI.

Lithium.

(1) Neither chlorplatinic acid nor tartaric acid gives a precipitate. (*Compare* potassium.)

(2) On digesting in concentrated solution with sodium phosphate, a white precipitate of trilithium phosphate is obtained, which is fusible (distinction from magnesium and alkaline earth metals).

(3) On warming with ammonium carbonate and ammonia, concentrated solutions give a white precipitate of the slightly soluble carbonate. (*Compare* alkali carbonates.) In presence of large amounts of alkali chlorides or ammonium chloride, no precipitate is obtained.

Separation from Sodium and Potassium.

Of the anhydrous chlorides, only the lithium salt is soluble in ether-alcohol mixture and in amyl alcohol.

REAGENTS.

CONCENTRATED ACIDS AND ALKALIES.

Hydrochloric acid, Sp. Gr. 1·19	38%
Nitric acid, Sp. Gr. 1·40	65%
Sp. Gr. 1·20	32·5%
Sulphuric acid, Sp. Gr. 1·84	96%
Acetic acid, Freezing pt. 7°C.	93%
glacial, Freezing pt. 17°C. ...	98%
Ammonia, Sp. Gr. 0·880	35%
Sp. Gr. 0·905	27%

SATURATED SOLUTIONS.

At 15° C. 100 grm. of solution contain :

Chlorine water	0.73 grm. Cl.
Bromine water	3.66 grm. Br.
Hydrogen sulphide water	0.48 grm. H_2S.
Baryta water ... ... 5.95 grm.	$Ba(OH)_2.8H_2O$
Lime water	0.17 grm. $Ca(OH)_2$.
Calcium sulphate solution ...	0.21 grm. $CaSO_4$.

SPECIAL REAGENTS.

Ammonium molybdate solution. 150 grm. of ammonium molybdate $[(NH_4)_6Mo_7O_{24}.4H_2O]$ are dissolved in a litre of water, and the solution poured into a litre of nitric acid (Sp. Gr. 1·2).

As a test for phosphate and arsenate, the reagent must be used in large excess, and the test is more delicate in presence of an equal volume of a concentrated solution of ammonium nitrate. In the case of arsenate the precipitate only forms rapidly on heating.

The yellow precipitate is the insoluble ammonium (or potassium) salt of phospho- or arseno-molybdic acid, which is soluble. The ammonium salt dissolves in alkalies, and addition of magnesium chloride to the solution gives a white crystalline precipitate of magnesium ammonium phosphate or arsenate.

Ammonium sulphide. Hydrogen sulphide is passed through 3 parts of ammonia solution until saturated, and 2 parts of the same ammonia solution are added. Yellow ammonium sulphide is prepared by digesting this solution with powdered (roll) sulphur.

Aqua regia. 1 volume of concentrated nitric acid mixed with 4 volumes of concentrated hydrochloric acid.

Cobalt reagent. α-Nitroso-β-naphthol is used in the form of its sodium salt, obtained by dissolving 0·1 grm. in 2 cc. of 2N caustic soda diluted to one litre.

Fehling's solution.
A: 34.6 grm. of $CuSO_4.5H_2O$ in 500 cc. of water.
B. 173 grm. of Rochelle salt and 65 grm. of caustic soda in 500 cc. of water.
Equal volumes are mixed just before use.

Fusion mixture (for dry-way tests). Equi-molecular proportions of dry sodium carbonate and potassium carbonate.

Hydrofluosilicic acid. Mixture of 1 part of calcium fluoride, 1 part of sand, and 6 parts of sulphuric acid is distilled, the leading tube dipping under mercury, on top of which is a layer of water. The solution is decanted and filtered.

Hydrogen peroxide. 2 per cent. solution (ten volumes of available oxygen).

Magnesia mixture. 100 grm. of $MgCl_2.6H_2O$ are dissolved in a litre of water, 250 grm. of ammonium chloride, and then 300 grm. ammonia (Sp. Gr. 0·880) added. After allowing to stand for several days the clear liquid is used.

Nessler solution. 35 grm. of potassium iodide and 12·5 grm. of mercuric chloride are dissolved in about 800 cc. of water. 120 grm. of caustic sode are dissolved in this, and the solution allowed to cool. Saturated mercuric chloride solution is then added drop by drop with constant stirring until a slight red precipitate remains. The solution is diluted to a litre, the precipitate allowed to settle, and the clear liquor siphoned off, and preserved in the dark.

The intensely coloured compound found in presence of ammonia is dimercuriammonium iodide, $NHg_2''I$.

Nickel reagents :

Dimethylglyoxime is used in 1 per cent. alcoholic solution, or in saturated aqueous solution, in which case the mixture must be allowed to stand to obtain the pink precipitate.

α-Benzildioxime is more easily prepared and is more delicate as a reagent for nickel. It is obtained by digesting an alcoholic solution of benzil with an equal weight of hydroxylamine hydrochloride. The precipitate obtained is washed twice with 50 per cent. alcohol. For qualitative purposes it is conveniently used in the form of the sodium salt, prepared by dissolving 0·1 grm. of the compound in

5 cc. of 2N caustic soda diluted to one litre. One cc. of this reagent is added to the solution under examination, which should contain ammonia and ammonium chloride.

Nitrite reagent (Ilosvay). See Nitrites, p. 35.

Nitrate reagent (Diphenylamine test). See Nitrates, p. 34.

Sodium cobaltinitrite A fresh 1 per cent. solution is used, and gives the yellow, crystalline $K_2Na[Co(NO_2)_6].H_2O$ in neutral or acetic acid solution.

Starch solution. The starch is ground with water to a thin cream, which is poured into sufficient boiling water to produce a 1 per cent. solution. The cold, clear solution is decanted for use. (After keeping for some time, the colour obtained with iodine is not so intense as with a fresh solution; it may, however, be preserved for a longer period by the addition of several drops of chloroform.)

IMPURITIES IN REAGENTS.

In the following notes, the more probable impurities which may be present in stated reagents are given.

Before testing for impurities, reagents must be diluted if necessary to a suitable concentration. Only tests of a special character have been inserted. Tests of a general character are :

(1) Volatile substances should leave no residue.

(2) Acid or alkaline reaction of a solid, which should give a clear solution if soluble in water.

(3) Test for heavy metals by means of ammonium sulphide.

As the testing of reagents is largely a matter of testing for *traces* of impurities, tests should be allowed to stand for several hours.

Acetic acid. Test for common mineral acids, and for copper, lead, iron, and calcium, also for sulphite.

After mixing the dilute acid (1 : 3) with twice its volume of N/100 permanganate, the colour should remain after standing fifteen minutes.

Ammonia. Test for chloride and sulphate. Also for carbonate by warming with lime water, and for pyridine, etc., by almost neutralising the dilute solution (1 : 3) with dilute sulphuric acid, using methyl orange as indicator, when the liquid obtained should be odourless. The concentrated

solution should not give a yellow or pink coloration on acidifying with nitric acid (1 : 1).

Ammonium carbonate. Test for chloride, iodide, sulphate, and thiocyanate. Test for organic matter by evaporating with excess of nitric acid; the residue should be white.

Ammonium chloride. Test for sulphate, phosphate, thiocyanate, and organic matter (see *ammonium carbonate*).

A 5 per cent. solution should be neutral (even the purest commercial samples are acid, and contain traces of iron).

Ammonium fluoride. Test for chloride and sulphate. Acidity indicates presence of bifluoride. Lead generally present. On volatilisation, 10 grm. should give only 2-3 mgm. residue.

Ammonium nitrate. See *ammonium chloride*. Test for nitrite.

Ammonium oxalate. Test for chloride, sulphate, free ammonia, free oxalic acid, and for potassium.

Ammonium sulphate. Test for chloride, nitrate, phosphate, thiocyanate, and arsenic.

Ammonium sulphide solution. Test for carbonate by warming with lime water, for free ammonia by warming with magnesium chloride, and for arsenic.

Ammonium thiocyanate. Test for chloride and sulphate. 1 grm. should dissolve completely in 10 cc. of alcohol. A 5 per cent. solution should remain colourless after addition of dilute hydrochloric acid. It is essential that the sample should be pure white, as yellowish samples contain organic matter. Traces of lead and iron, and of sulphuric acid are frequently present in commercial samples.

Barium carbonate. The filtrate obtained by adding sulphuric acid to a hydrochloric acid solution should not leave any residue on evaporation and ignition.

Barium chloride. Test for chlorate by warming 2 grm. with 10 cc. of concentrated hydrochloric acid. Commercial samples frequently contain traces of iron and potassium, and are moist, due to the presence of calcium chloride.

Barium hydroxide. Test for chloride. Commercial samples contain sulphate, sulphite, sulphide, and thiosulphate. Sample should be completely soluble in water, or leave only a slight residue of barium carbonate.

Barium nitrate. Test for chloride and for lead.

Bromine. Test for chlorine, iodine, sulphur and organic compounds (bromoform, etc.), as follows : Convert several grams into ammonium bromide by adding water and then slowly adding an excess of ammonia. A residue of oily drops indicates the presence of organic compounds. Traces

of iodide are detected by adding ferric chloride and chloroform. Traces of chloride are detected by using the fact that silver chloride is soluble in warm ammonium sesquicarbonate solution (1 part of ammonium carbonate, 1 part of ammonia, Sp. Gr. 0.96, and 3 parts of water) whereas the bromide is practically insoluble, and the iodide is quite insoluble.

Calcium chloride. Test for nitrate, sulphate, ammonium compounds, and iron. 1 grm. should dissolve completely in 10 cc. of alcohol. A 5 per cent. solution should remain clear on standing with calcium sulphate solution.

Calcium oxide. Test for chloride, sulphate, carbonate, silica, alumina and iron.

Copper sulphate. Test for iron and zinc.

Ferric chloride. Test for free hydrochloric acid, by bringing the stopper of an ammonia bottle near to the solid. Also for free chlorine with starch-iodide paper, and for arsenic, copper, zinc, ferrous chloride, sulphates and nitrates. Sample should be completely soluble in ether.

Hydrochloric acid. Test for sulphate, sulphurous acid, free chlorine, other halogen acids, and for iron, arsenic, aluminium, and calcium.

Hydrogen peroxide. Test for chloride, fluoride, hydrofluosilicate, sulphate, phosphate, alumina, magnesia, and free acid.

Iodine. Add ammonia to the aqueous extract and test for chloride and bromide. Test another aqueous extract for cyanogen by adding sodium thiosulphate until decolorised, then a crystal of ferrous sulphate, a drop of ferric chloride solution, and several drops of caustic soda; warm the solution and acidify with hydrochloric acid, when no blue colour should be developed.

Lead acetate. Test for chloride, nitrate, alkaline earth metals, copper, and iron.

Nickel salts. Test for aluminium and cobalt.

Nitric acid. Test for sulphuric acid in the residue obtained by evaporating 10 cc. to 0·5 cc.; for hydrochloric acid by adding 10 cc. to 50 cc. of water containing several drops of silver nitrate solution; for iodine compounds (iodic acid, etc.) by diluting with an equal volume of water, adding a piece of zinc and then carbon disulphide to extract any iodine liberated; also test for iron and arsenic.

Oxalic acid. Test for sulphate, ammonia, sodium, potassium, calcium, and iron. The crystals should not have effloresced.

Phosphoric acid. Test for nitric acid, halogen acids, sulphuric acid, metaphosphoric acid, ammonia, and arsenic.

On boiling 5 cc. with 5 cc. of sulphuric acid and 5 drops of potassium permanganate (0.1 per cent.), the red colour should persist after five minutes, indicating the absence of lower phosphorus acids and of organic matter.

Potassium bisulphate. Test for chloride, nitrate, and arsenic.

Potassium carbonate. Test for chloride, chlorate, nitrate, sulphate, phosphate, silicate, cyanide, sulphide, sodium and aluminium.

Potassium chlorate. Test for chloride, nitrate, sulphate, sodium, calcium, lead, and arsenic.

Potassium chloride. Test for sulphate, calcium, and manganese

Potassium chromate. Test for chloride, sulphate, aluminium and calcium. Phenolphthalein should not give a red colour with a 0.5 per cent. solution.

Potassium cyanide. Test for chloride, sulphate, cyanate, thiocyanate, and ferrocyanide, and for sodium.

Potassium dichromate Test for sulphate, chloride, calcium and aluminium.

Potassium ferrocyanide. Test for chloride, sulphate, and sodium.

Potassium hydroxide. Test for chloride, nitrate, nitrite, carbonate, sulphate, phosphate, silicate, sulphide, calcium and aluminium.

Potassium iodide. Test for carbonate (by alkalinity to litmus paper), chloride and bromide, iodate, nitrate, sulphate, sulphite and cyanide.

Potassium nitrate. Test for chloride, chlorate, perchlorate, sulphate, calcium, and sodium.

Potassium nitrite. Test for free alkali, carbonate, chloride, nitrate, sulphate, and lead.

Potassium permanganate. Test for chloride and sulphate after boiling a solution with alcohol, and for nitrate after decolorising with oxalic acid.

Sodium acetate. Test for common mineral acids.

Sodium carbonate. Test for chloride, sulphate, thiosulphate, phosphate, silicate, ammonia, iron, arsenic, calcium, and potassium.

Sodium chloride. Test for sulphate, iodide (by ferric chloride and starch), ammonia, calcium, magnesium, and potassium.

S

Sodium hydroxide. Test for chloride, nitrate, carbonate, sulphate, phosphate, borate, silicate, ammonia, aluminium, iron, calcium, and potassium.

Sodium nitrite. See *potassium nitrite*, also test for potassium by means of sodium cobaltinitrite

Sodium phosphate. Test for chloride, nitrate, carbonate, sulphate, arsenic, potassium, and calcium.

Table of the Limits of Lead and Arsenic

allowed in the Drugs of the British Pharmacopœia, 1914.

Strictly speaking, the British Pharmacopœia is not a legal standard, but it is a presumptive one for the articles and preparations named in it. Details for applying the tests for lead and arsenic are given in Appendices V and VI of the B.P. The last edition (1914) now uses the terms " purified alum " and " purified borax " to distinguish the medicinal from the commercial varieties. It also includes glucose, but in view of the " salts of tartar " litigation during 1914 the synonym " salts of tartar " for potassium carbonate has been omitted :

	Parts per Million.	
	Pb.	As.
Acid, acetic (33% CH_3COOH)	–	2
,, acetylsalicylic	10	2
,, benzoic	–	2
,, boric	25	5
,, citric	20	1.4
,, hydriodic dilute (10% HI)	10	5
,, hydrobromic dilute (10% HBr)	5	5
,, hydrochloric (31.79% HCl)	10	5
,, lactic (75% lactone, 10% acid)	10	5
,, nitric (70% HNO_3 Sp. Gr. 1.42)	20	5
,, phosphoric conc. (Sp. Gr. 1.5) 66.3% H_3PO_4	10	5
,, salicylic	–	2
,, sulphuric (Sp. Gr. 1.841) 95% H_2SO_4	20	5
,, sulphurous (5% SO_2)	10	5
,, tartaric	20	1.4
Alum, purified (NH_4 or K)	0	5
Ammonia solution, strong (Sp. Gr. 0.888) ..	–	0.5
Ammonium benzoate	10	2
,, bromide	10	5
,, carbonate	5	2
,, chloride	5	5

	Parts per Million.	
	Pb.	As.
Antimony, sulphuretted	–	1000
Bismuth carbonate	–	–
,, salicylate	–	2
,, subnitrate	–	2
Borax, purified	5	5
Calcium carbonate pptd.	10	5
,, chloride	20	5
,, hydroxide	20	5
,, hypophosphite	10	5
,, lactate	10	5
,, oxide	–	5
,, phosphate	–	5
Chalk, prepared	–	5
Copper sulphate	–	10
Ferric chloride solution, strong	–	10
,, sulphate solution	–	5
Ferrous sulphate	–	2
,, ,, exsiccated (77% FeSO$_4$)	–	5
,, carbonate, saccharated	–	5
Glucose	–	2
Glycerin	–	4
Iron (wire or nails)	–	200
,, reduced	–	200
,, ammonium citrate	–	5
,, potassium tartrate	–	5
,, and quinine citrate	–	5
Lithium carbonate	10	5
,, citrate	5	2
Magnesium bicarbonate solution	0.5	0.2
,, carbonate	20	5
,, oxide	20	5
,, sulphate	5	5
Potassium acetate	10	5
,, bicarbonate	5	5
Potassium bromide	10	5
,, carbonate	5	2
,, chlorate	10	5
,, citrate	10	2
,, iodide	10	5
,, nitrate	10	5
,, sulphate	20	5
,, tartrate	20	2
,, ,, acid	20	2

		Parts per Million.	
		Pb.	As.
Sodium benzoate		10	2
,, bicarbonate		5	2
,, bromide		10	5
,, carbonate		10	2
,, ,, exsiccated (95% Na_2CO_3)		25	5
,, chloride		10	2
,, hypophosphite		10	5
,, iodide		10	5
,, nitrite		–	5
,, phosphate		5	5
,, ,, acid		5	2
,, potassium tartrate		20	2
,, salicylate		10	2
,, sulphate		5	2
,, sulphite		–	5
Strontium bromide		20	5
Sulphur, pptd.		–	5
,, sublimed		·	5
Zinc acetate		··	5
,, carbonate		··	10
,, chloride		··	5
,, oxide		··	10
,, sulphate		··	5
,, valerianate		–	5

Table of the Limits of Impurities

allowed in the Drugs of the United States Pharmacopœia, 9th Revision, 1916.

The U.S. Pharmacopœia and the National Formulary are the standards for drugs under the Pure Food and Drugs Act of June 30, 1906. "Standards of purity and strength, prescribed in the text of this Pharmacopœia, are intended solely to apply to substances which are used for medicinal purposes or in determining the identity or purity of such substances."

The following U.S.P. drugs are required to be free from arsenic (indicated by *) and/or heavy metals (lead, copper, etc., indicated by †), within the limits of the tests for impurities given in U.S.P., Part II, p. 584 :—

Acid, acetic (36.5% CH₃.COOH)		†
Acid, boric	*	†
Acid, citric		†
Acid, hydriodic, dilute (10% HI)	*	†
Acid, hydrobromic, dilute (10% HBr)	*	†
Acid, hydrochloric (Sp. Gr. 1.155/25°)	*	†
Acid, hypophosphorous	*	†
Acid, lactic		†
Acid, nitric (Sp. Gr. 1.403)	*	†
Acid, phosphoric	*	†
Acid, sulphuric (Sp. Gr. 1.83)	*	†
Acid, tartaric		†
Alum (NH₄ or K)	*	†
Aluminium hydroxide	*	†
Ammonium benzoate		†
Ammonium bromide		†
Ammonium carbonate		†
Ammonium chloride		†
Ammonium hydroxide		†
Ammonium iodide		†
Ammonium salicylate		†
Ammonium valerate		†
Antimony-potassium tartrate	*	
Antipyrine		†
Bismuth-ammonium citrate	*	†
Bismuth beta-naphthol	*	†
Bismuth subcarbonate	*	†
Bismuth subgallate	*	†
Bismuth subnitrate	*	†
Bismuth subsalicylate	*	†

Caffeine citrate	†
Caffeine-sodium benzoate	†
Calcium bromide	†
Calcium carbonate, precipitated	†
Calcium chloride	†
Calcium glycero-phosphate	†
Calcium hypophosphite .. .. *	†
Calcium lactate	†
Cerium oxalate .. .. *	†
Copper sulphate	†
Ferrous sulphate	†
Gelatin	*
Glucose .. .. *	†
Glycerin .. .. *	†
Hydrogen peroxide (3%) .. .. *	†
Iron, reduced	*
Lactose	†
Lithium bromide	†
Lithium carbonate	†
Lithium citrate	†
Magnesium carbonate	†
Magnesium oxide	†
Magnesium sulphate .. .. *	†
Methyl salicylate	†
Methyl-thionine chloride	*
Oil of anise	†
Oil of bitter almond	†
Oil of cinnamon	†
Phenol-phthalein	†
Potassium acetate .. .. *	†
Potassium bicarbonate	†
Potassium bitartrate	†
Potassium bromide	†
Potassium carbonate	†
Potassium chlorate	†
Potassium citrate .. .. *	†
Potassium-sodium tartrate	†
Potassium hydroxide	†
Potassium hypophosphite	*
Potassium iodide	†
Potassium nitrate	†
Salicin	†
Sodium acetate .. .. *	†
Sodium arsenate	†
Sodium benzoate	†
Sodium bicarbonate	†

Sodium borate .. .. * †
Sodium bromide .. .. †
Sodium cacodylate .. .. †
Sodium carbonate, monohydrated .. .. †
Sodium chloride .. .. †
Sodium citrate .. .. * †
Sodium glycero-phosphate .. .. †
Sodium hydroxide .. .. †
Sodium hypophosphite .. .. * †
Sodium iodide .. .. †
Sodium nitrite .. .. †
Sodium perborate .. .. †
Sodium phenol-sulphonate .. .. †
Sodium phosphate, dibasic .. .. * †
Sodium salicylate .. .. †
Sodium sulphate .. .. * †
Sodium sulphite, exsiccated .. .. * †
Sodium thiosulphate .. .. * †
Strontium bromide .. .. †
Strontium iodide .. .. †
Strontium salicylate .. .. †
Sulphur .. .. *
Uranium nitrate .. .. †
Zinc acetate .. .. * †
Zinc carbonate, precipitated .. .. †
Zinc chloride .. .. †
Zinc oxide .. .. †
Zinc phenol-sulphonate .. .. * †
Zinc sulphate .. .. * †
Zinc valerate .. .. * †

VOLUMETRIC ANALYSIS.

STANDARD SOLUTIONS.

The term *normal* (N) is used to indicate a solution of which one litre contains the gram-equivalent of the dissolved substance. *Seminormal* (N/2), *decinormal* (N/10), *centinormal* (N/100), etc., solutions contain 1/2, 1/10, 1/100, etc., of the gram-equivalent per litre. For example, as hydrochloric acid is a monobasic acid, a normal solution contains 36·47 grm. per litre (HCl = 36·47), whereas a normal solution of sulphuric acid, a dibasic acid, contains 98·08/2 = 49·04 grm. per litre ($H_2SO_4 = 98·08$).

Similarly normal caustic soda contains 40·01 grm. per litre (NaOH = 40·01), whereas normal sodium carbonate contains 106·00/2 = 53·00 grm. per litre ($Na_2CO_3 = 106·00$)

Correction of Burette Readings to 15°C. (Schlösser).

	Correction in cc. for 1 litre of						
°C.	N. HCl	N. H_2SO_4	N. HNO_3	N. $H_2C_2O_4$	N. NaOH	N. Na_2CO_3	N/10 solns.
5	+1.26	+1.94	+2.00	+1.33	+2.18	+2.03	+0.60
6	1.18	1.79	1.84	1.25	1.99	1.87	0.60
7	1.10	1.63	1.68	1.16	1.80	1.69	0.59
8	1.00	1.46	1.50	1.06	1.60	1.50	0.56
9	0.88	1.28	1.31	0.94	1.39	1.31	0.52
10	0.76	1.09	1.11	0.81	1.18	1.11	0.46
11	0.63	0.89	0.91	0.67	0.96	0.90	0.40
12	0.48	0.68	0.69	0.52	0.73	0.69	0.32
13	0.33	0.46	0.46	0.35	0.50	0.47	0.22
14	0.17	0.23	0.23	0.18	0.25	0.24	0.12
15	0.0	0.00	0.00	0.00	0.00	0.00	0.00
16	−0.18	−0.24	−0.25	−0.20	−0.25	−0.24	−0.13
17	0.36	0.49	0.50	0.40	0.51	0.49	0.27
18	0.56	0.75	0.76	0.61	0.78	0.75	0.42
19	0.76	1.02	1.03	0.82	1.05	1.02	0.59
20	0.97	1.30	1.30	1.05	1.33	1.29	0.76
21	1.19	1.58	1.58	1.29	1.62	1.57	0.95
22	1.41	1.86	1.87	1.54	1.92	1.85	1.14
23	1.64	2.15	2.17	1.80	2.23	2.14	1.35
24	1.88	2.45	2.47	2.07	2.54	2.44	1.56
25	2.14	2.76	2.78	2.34	2.85	2.75	1.79
26	2.40	3.08	3.10	2.62	3.17	3.06	2.02
27	2.67	3.41	3.43	2.90	3.50	3.38	2.27
28	2.95	3.75	3.76	3.19	3.83	3.70	2.52
29	3.23	4.09	4.10	3.49	4.17	4.04	2.78
30	3.52	4.43	4.44	3.82	4.52	4.38	3.06

STANDARD SOLUTIONS OF ACIDS, ALKALIES AND SALTS.

NOTE.—The formulæ given represent the commercial form of the salt; the figures, the number of grams of solid (including water of crystallisation, if definite) contained in a litre of the NORMAL *solution; and the* NORMALITY *of the solution suggested for general use in the laboratory is given in brackets.*

Acetic acid	60·04	(2N)
Ammonia	17·03	(2N)
Ammonium carbonate	(20% solution)	
Ammonium chloride, NH_4Cl	53·50	(2N)
Ammonium oxalate, $(NH_4)_2C_2O_4.H_2O$	71·06	(N/2)
Ammonium sulphate	66·07	(N)
Arsenious oxide, As_4O_6	49·48	
Barium chloride, $BaCl_2.2H_2O$	122·16	(N)
Calcium chloride, $CaCl_2 + x$ aq.	55·50	(N)
Caustic potash	56·11	(2N)
Caustic soda	40·01	(2N)
Cobalt nitrate, $Co(NO_3)_2.6H_2O$	145·54	(N)
Copper sulphate, $CuSO_4.5H_2O$	124·85	(N/2)
Ferric chloride, $FeCl_3 + x$ aq.	54·08	(N)
Hydrochloric acid	36·47	(2N)
Lead acetate, $Pb(C_2H_3O_2)_2.3H_2O$	189·66	(N)
Magnesium sulphate, $MgSO_4.7H_2O$	123·24	(N)
Mercuric chloride, $HgCl_2$	135·76	(N/2)
Mercurous nitrate, $Hg_2(NO_3)_2$	262·3	(N)
Nitric acid	63·02	(2N)
Oxalic acid, $H_2C_2O_4.2H_2O$	63·03	
Potassium dichromate, $K_2Cr_2O_7$	49·03	(N)
Potassium ferrocyanide, $K_4Fe(CN)_6.3H_2O$	105·62	(N)
Potassium iodide, KI	166·02	(N/2)
Potassium permanganate, $KMnO_4$	31·61	(N)
Potassium thiocyanate, $KCNS$	97·18	(N/2)
Silver nitrate, $AgNO_3$	169·9	(N/10)
Sodium carbonate, Na_2CO_3	53·00	(2N)
Sodium phosphate, $Na_2HPO_4.12H_2O$	119·4	(N/2)
Sodium thiosulphate, $Na_2S_2O_3.5H_2O$	124·10	(N/2)
Stannous chloride, $SnCl_2.2H_2O$	112·8	(N)
Sulphuric acid	49·04	(2N)
Zinc sulphate, $ZnSO_4.7H_2O$	143·8	(N/2)

Neutralisation Methods.

Standards.

Numerous substances have been recommended for use as standards in acidimetry and alkalimetry on account of the purity of samples readily obtained.

Sodium carbonate, prepared by heating the bicarbonate (well washed with ice-cold water) at 180—200°C. until constant in weight, must be heated in the air-oven each time before use.

Organic acids (*e.g.* recrystallised oxalic acid) have been recommended. As phenolphthalein is used as indicator, the alkali solution employed must be free from carbonate. Such a solution is prepared by careful addition of baryta water to the caustic alkali solution.

Phenolphthalein cannot be used with weak alkalies such as ammonia; in titrating with alkalies, the titration should be continued until the maximum red colour is obtained; titrations with acid should proceed until the solution is quite colourless.

Methyl orange may be used for the titration of the alkali salts of weak acids.

Methyl red is recommended particularly in case solutions of less than N/10 strength are being employed.

Combined ammonia. The neutral solution is boiled with a measured excess of standard alkali and titrated back with standard acid, using methyl orange as indicator.

Estimation of nitrates as ammonia. 1 grm. of the commercial nitrate is dissolved in 250 cc. of water, 25 cc. withdrawn into the flask (preferably of copper) of an ammonia distillation apparatus, 100 cc. of dilute caustic soda and then exactly 20 cc. of titanous chloride or sulphate solution (20 per cent.) added. The solution is distilled for twenty minutes, and the ammonia produced collected in decinormal sulphuric acid; the excess is titrated with decinormal alkali. The distillation is repeated in absence of nitrate, using the same volume of titanous chloride solution, in order to ascertain the amount of ammonia due to nitrogen compounds in this reagent. (It is now stated that it is unnecessary to carry out a "blank" on the titanous chloride.)

Estimation of total alkali in water-glass. 1–2 grm. of water-glass are weighed out, dissolved in 50 cc. of hot water in a porcelain dish, the solution diluted to 200 cc., and titrated with normal sulphuric acid, using methyl orange as indicator.

Valuation of borax. (a) *Total alkali* is estimated by titration with normal sulphuric acid, using methyl orange as indicator, when all the boric acid is liberated.

(b) After heating the neutralised solution from (a) *almost* to the boiling-point, to free from carbon dioxide, it is mixed with an equal bulk of neutral glycerin solution (prepared by mixing glycerin with an equal volume of water, adding phenolphthalein, and titrating with caustic soda). The mixture is then titrated with normal caustic soda, the phenolphthalein acting as indicator. The B_2O_3 is converted into metaborate ($NaBO_2$).

Valuation of argol. 2 grm. are weighed accurately into a porcelain crucible. The total amount of tartrate present is determined by igniting over a small Bunsen flame to convert into carbonate. The residue is extracted with water, the liquid filtered, and the potassium carbonate in the solution titrated with standard acid.

The percentage of bitartrate ($KHC_4H_4O_6$) present is ascertained by dissolving 2–3 grm. in hot water and titrating with caustic soda, using phenolphthalein as indicator. From this the amount of potassium carbonate formed in the above ignition due to bitartrate may be calculated, and then the amount due to neutral tartrate ($K_2C_4H_4O_6$), from which the percentage of neutral tartrate may be obtained.

Oxidation Methods.

(1) Potassium Permanganate and Potassium Dichromate.

In presence of oxidisable material, an acid solution of potassium permanganate contains available oxygen according to the following equation:

$$2KMnO_4 + 4H_2SO_4 = 2KHSO_4 + 2MnSO_4 + 3H_2O + 5O.$$
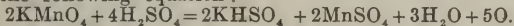
That is, $2KMnO_4$ are equivalent to $5O$. Hence a decinormal solution of potassium permanganate, 1 litre of which is to be equivalent to 8 grm. of oxygen, must contain (for use in acid solution)

$$\frac{2(158)}{2 \times 5 \times 10} = 3\cdot16 \text{ grm. } KMnO_4 \text{ per litre.}$$

In case the permanganate is used in neutral or alkaline solution, a decinormal solution will contain

$$\frac{2(158)}{2 \times 3 \times 10} = 5\cdot267 \text{ grm. } KMnO_4 \text{ per litre,}$$

based on the equation:

$$2KMnO_4 + H_2O = 2MnO_2 + 2KOH + 3O.$$
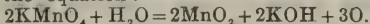
In the titration of oxalic acid (in presence of sulphuric acid and at 60–70° C.), the reaction which occurs may be represented as follows :

$$(COOH)_2 + O = 2CO_2 + H_2O.$$

In the estimation of hydrogen peroxide (in sulphuric acid solution), the reaction may be represented as follows :

$$H_2O_2 + O = H_2O + O_2.$$
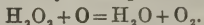
In the estimation of ferrocyanides (in presence of a large amount of sulphuric acid), the reaction involved is the oxidation of $H_4Fe(CN)_6$ to $H_3Fe(CN)_6$.

In the estimation of nitrite, it is preferable to titrate with the nitrite solution into the warm diluted permanganate, the reaction being :

$$HNO_2 + O = HNO_3.$$
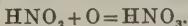
Similar reasoning to the above applies to a decinormal solution of potassium dichromate (used in presence of hydrochloric acid), a decinormal solution of which contains

$$\frac{294\cdot2}{2 \times 3 \times 10} = 4\cdot903 \text{ grm. } K_2Cr_2O_7 \text{ per litre,}$$

based on the equation :

$$K_2Cr_2O_7 + 5H_2SO_4 = 2KHSO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O.$$
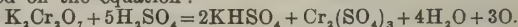
Standards.

Recrystallised ammonium oxalate or very carefully purified oxalic acid may be used in standardising potassium permanganate (in sulphuric acid solution at 60–70° C.).

Ferrous ammonium sulphate is available for standardising potassium permanganate (in sulphuric* acid solution) or potassium dichromate (in hydrochloric acid solution), but must be carefully prepared, as the iron content of commercially pure samples frequently differs from the theoretical value. The indicator used in titrations with potassium dichromate is a dilute solution of potassium ferricyanide

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*It has been stated that the presence of manganese sulphate prevents the interaction of hydrochloric and permanganic acids; it is, however, inadvisable to titrate with permanganate in presence of hydrochloric acid, dichromate being available in such a case. For example, in the estimation of a ferric salt, the ferric salt may be reduced (a) with zinc and sulphuric acid, the ferrous salt being titrated with permanganate; or (b) with zinc and hydrochloric acid which is much quicker, or even more rapidly with stannous chloride solution (the excess of which is oxidised by careful addition of mercuric chloride solution), in which case the ferrous salt is titrated with dichromate.

(freshly prepared from washed crystals), employed as an outside indicator on a spot plate to show when the conversion of $Fe^{..}$ to $Fe^{...}$ is complete.

(2) Iodimetry.

The following equation represents the reaction between iodine and sodium thiosulphate, resulting in the formation of sodium tetrathionate :

$$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI.$$
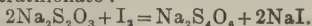
Sodium thiosulphate solution should be preserved in full, stoppered bottles, out of contact with air containing carbon dioxide, which causes precipitation of sulphur.

Standards.

Sodium thiosulphate solution may be standardised against decinormal permanganate as follows : 25 cc. of standard permanganate are acidified with 10 cc. of dilute sulphuric acid, 10 cc. of a 10 per cent. solution of potassium iodide added, and the iodine liberated titrated with thiosulphate solution until of a pale yellow tint, and then either (i) a few cc. of a freshly prepared starch solution added and the liquid titrated until the violet colour finally disappears, or (ii) 1 cc. of a 0.5 per cent. solution of methylene blue added and the liquid titrated until the brown colour has changed through green to blue.

In case the thiosulphate is to be used for the determination of copper, it is preferable to standardise in the following manner : 0.3 grm. of electrolytic copper are dissolved in 10 cc. of nitric acid (1 : 1) in a conical flask, inclined in order to prevent spurting, the solution diluted with 20 cc. of water and boiled for a few moments to expel nitric fumes. The solution is rinsed into a beaker, sodium carbonate added until the liquid is opalescent, and then a slight excess of acetic acid added. 10 cc. of a 10 per cent. solution of potassium iodide are added and the iodine liberated titrated with thiosulphate solution until the precipitate is almost white; starch solution is then added and the liquid titrated until it remains colourless on standing for one minute.

Standard iodine solution is prepared by dissolving 13 grm. of iodine in a litre of water containing 30 grm. of potassium iodide, and is standardised against decinormal thiosulphate.

Valuation of bleaching powder. 10–12 grm. of sample of bleaching powder are ground to a paste with water in a porcelain mortar, and more water added. After allowing to settle, the turbid liquid is decanted into a litre flask. The

residue is ground with further amounts of water until the whole of the solid has been transferred to the flask. The liquid is made up to a litre, 25 cc. of the turbid liquid withdrawn by pipette, 10 cc. of a 10 per cent. solution of potassium iodide added, the solution acidified with acetic acid, and titrated with decinormal thiosulphate.

An alternative method is to use a standard solution of arsenious oxide, prepared by dissolving 4.95 grm. of arsenious oxide in caustic soda, acidifying with hydrochloric acid, and adding an excess of sodium bicarbonate. The reaction used is as follows :

$$As_2O_3 + 2I_2 + 4NaHCO_3 = As_2O_5 + 4NaI + 4CO_2 + 2H_2O.$$
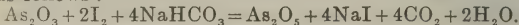
A measured excess of arsenious oxide is added to the bleaching powder solution prepared as above, and the excess titrated with decinormal iodine; or, the bleaching powder solution may be titrated directly with the standard arsenious oxide solution, using starch-iodide paper as an external indicator.

Estimation of chlorate. Owing to the possible presence of free chlorine in hydrochloric acid and of iodate in the potassium iodide, a "blank" must be carried out in this estimation. 10 grm. of potassium iodide (weighed to the nearest decigram) dissolved in about 50 cc. of water, and 20 cc. of concentrated hydrochloric acid, are placed in each of two 250 cc. bottles with well-fitting glass stoppers. About 0.5 grm. of commercial chlorate is dissolved in water, and added to the contents of one bottle. The stoppers are fastened to the necks of the bottles. The bottles are immersed in a steam bath for twenty minutes, removed and allowed to cool. The contents of the bottle to which chlorate has been added are made up to 250 cc. in a measuring flask, and 25 cc. titrated with decinormal thiosulphate, using starch or methylene blue as indicator. The contents of the other bottle are titrated direct, and the suitable correction subtracted from the previous titration.

Determination of sulphite. 5 grm. of commercial sulphite are dissolved in 250 cc. of water. 25 cc. are withdrawn, a measured excess of decinormal iodine added, and the excess titrated with decinormal thiosulphate.

(3) Titanous Chloride and Methylene Blue.

For many purposes the use of standard solutions ($N/50$ to $N/40$) of these two reagents has decided advantages over the methods at present more frequently adopted. Examples are the estimation of iron as ferric salt, chromium as chromate, stannous chloride, and of other substances which

act as, or may be quantitatively converted into, oxidising or reducing agents. Contrary to general impression, these reagents are comparatively cheap.

The standard solution of methylene blue is quite stable, but the preservation of standard titanous chloride necessitates the use of a special storage apparatus. The storage vessel is filled with a thoroughly mixed solution containing 25 cc. of 20 per cent. titanous chloride solution and 50 cc. of concentrated hydrochloric acid per litre. By opening the burette tap, a current of hydrogen from the generator, B, may be passed through the apparatus for five minutes. The contents of the storage vessel are again mixed, and the burette filled by opening the bead valve at A. After running off several cc., the apparatus is ready for use.

A standard solution of methylene blue is prepared by dissolving 4–5 grm. of the hydrochloride (free from zinc) in 500 cc. of hot water, and diluting to a litre. A standard solution of pure potassium chlorate is also prepared by dissolving 0.6–0.7 grm. in a litre of cold, recently boiled water.

Standardisation of solutions.
(1) 50 cc. of the methylene blue solution are withdrawn into an 8 oz. conical flask, an equal volume of dilute hydrochloric acid added, and a current of carbon dioxide passed into the flask. The liquid is heated to boiling, and titrated whilst warm with the titanous chloride solution until the blue colour disappears. The current of carbon dioxide is maintained, and 25 cc. of the potassium chlorate solution added to the contents of the flask, the solution warmed to about 40°C. if necessary (to obtain a sharp end-point), and the warm
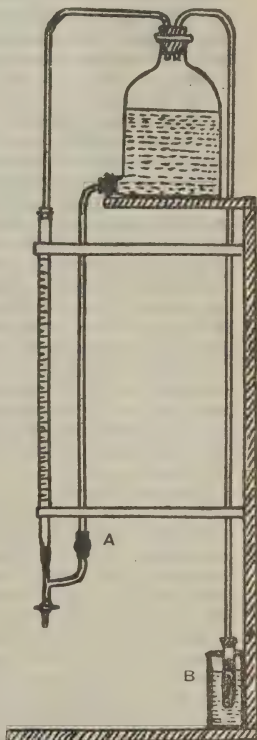
solution titrated with titanous chloride. The second titration gives the volume of titanous chloride equivalent to the oxygen available in 25 cc. of the standard potassium chlorate solution (due to its reduction to chloride by the reduced methylene blue), and hence the oxygen equivalent and iron equivalent of 1 cc. of titanous chloride may be calculated. The volume of titanous chloride equivalent to 50 cc. of methylene blue is known from the first titration, and from this the oxygen equivalent and iron equivalent of 1 cc. of methylene blue may be calculated.

(2) In case pure ferrous ammonium sulphate is available, and an iron estimation is to be carried out by means of titanous chloride, the following method may be used for standardising the titanous chloride solution :* 3–4 grm. of ferrous ammonium sulphate are dissolved in 100 cc. of water, an equal volume of dilute sulphuric acid added, and the solution made up to 250 cc. in a measuring flask. 25 cc. are oxidised with dilute potassium permanganate, an excess of which may be destroyed by adding hydrochloric acid and boiling for several minutes. A current of carbon dioxide is passed into the flask, 20 cc. of potassium thiocyanate solution added, and the solution titrated with titanous chloride solution until colourless.

Another method is to add 2 drops of methylene blue solution to the ferric salt solution, warm to about 40°C. and titrate with titanous chloride solution until decolorised. As the methylene blue requires 2 drops of titanous chloride for its decoloration, 0.1 cc. must be subtracted from the titration.

In case method (2) is used, as the titanous chloride solution oxidises slowly even in the special storage apparatus, it is convenient to keep a standard solution of iron alum, containing about 14 grm. per litre and acidified with sulphuric acid, for re-standardising purposes; this solution remains the same strength for an indefinite period, and may be standardised by titration with titanous chloride immediately after this reagent has been standardised as above. This is not necessary if the titanous chloride is to be used in conjunction with standard methylene blue, as the titration of the latter solution, which keeps its standard indefinitely, will serve as standardisation.

In practice it has been found advisable to standardise the titanous chloride solution against a pure sample of the

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* See Knecht and Hibbert, *New Reduction Methods in Volumetric Analysis.*

substance to be estimated, whenever possible, *e.g.* in estimating chromates, it should be standardised against pure potassium dichromate.

Determination of Ferric salt. 25 cc. of the ferric salt solution is diluted to 100 cc. with water, boiled for a few moments, allowed to cool to about 40°C. in an atmosphere of carbon dioxide, two drops of methylene blue added, and titrated as in method of standardisation (2) above. The titanous chloride is standardised against standard iron alum solution.

Another convenient method is as follows : 25 cc. of standard methylene blue are reduced with titanous chloride as in method of standardisation (1), by which means the reagent is standardised ; 25 cc. of the ferric salt solution are added, and the methylene blue produced by the reduction of the ferric salt titrated with titanous chloride.

Estimation of Chlorate. The procedure will be clear from a consideration of method of standardisation (1) above. The process is unaffected by the presence of perchlorates, which do not oxidise reduced methylene blue under these conditions.

Estimation of Chromium or Chromate. * 50 cc. of the solution containing a suitable amount of chromium are taken, a slight excess of caustic soda added, and then small amounts of sodium peroxide are added until the oxidation and solution of the chromium hydroxide is complete. After boiling for ten minutes to destroy the excess of sodium peroxide, the solution is diluted to 250 cc. 25 cc. of this solution are added to reduced methylene blue solution (the chromate is reduced to a chromic salt), and the methylene blue produced is titrated. A satisfactory method of estimating dichromates is as follows :—25 cc. of approx. N/30 dichromate and 10 cc. of N/30 iron alum are warmed to 60°C. and standardised titanous chloride added until the solution is a clear blue-green ; thiocyanate is added, and the titration continued until a clear green solution is obtained.

Estimation of Stannous Chloride. 1 grm. of commercial sample is dissolved in 50 cc. dilute hydrochloric acid, and made up to 250 cc. with cold, recently boiled water. 25 cc. are withdrawn into a conical flask through which a current of carbon dioxide is maintained, an equal volume of concen-

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* Chromium, vanadium, and iron may be estimated in presence of one another (Atack, *Analyst*, 1913).

trated hydrochloric acid added, and the solution titrated with standard methylene blue* until the blue colour persists. (In case the concentrated hydrochloric acid contains free chlorine, as is frequently the case, the necessary correction for its action in oxidising some stannous chloride is readily made by repeating the titration, using double the volume (50 cc.) of hydrochloric acid, when any decrease in the volume of methylene blue used is to be added to the first titration.)

Valuation of Hydrosulphite. 50 cc. of standard methylene blue are measured into a conical flask through which a current of carbon dioxide is maintained, 0.1 to 0.2 grm. of sodium hydrosulphite introduced from a weighing bottle, 10 cc. of acetic acid added, the liquid warmed, and the excess of methylene blue determined by means of titanous chloride (previously standardised against 25 cc. of the standard methylene blue). The percentage of $Na_2S_2O_4$ in the sample is calculated on the basis that one molecule requires one atom of oxygen for its oxidation.

Precipitation Methods.

(1) Silver Nitrate and Ammonium Thiocyanate.

Standard silver nitrate solution may be standardised against pure, fused sodium chloride.

In estimating halides or cyanide (in *neutral* solution) by means of decinormal silver nitrate, several drops of (neutral) potassium chromate solution are added, and the titration continued until the precipitate becomes reddish. Cyanides may be titrated direct with silver nitrate, the soluble double cyanide being formed until half the cyanide present has been converted into silver cyanide; further addition of silver nitrate gives an opalescence which marks the end-point, due to the precipitation of silver cyanide.

Standard thiocyanate solution may be standardised against decinormal silver nitrate or against pure silver foil dissolved in nitric acid (1 : 1). Ammonium thiocyanate solution is added to the *acid* solution of the silver salt containing ferric sulphate until, after allowing to settle, the clear liquid above the white ppt. has acquired a permanent blood-red

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* A method of standardising methylene blue which does not necessitate the use of titanous chloride has been described (Atack, *J. Soc. Dyers and Col.*, 1913, p. 9).

colour. A suitable solution of ferric sulphate is prepared by oxidising 100 cc. of a saturated solution of ferrous sulphate with 50 cc. of concentrated nitric acid, boiling to expel nitric fumes (nitrous acid must be absent). The presence of free nitric acid is essential, as lead, copper and zinc do not then affect the titration; mercury must be absent, and large amounts of copper mask the end-point.

(2) Potassium Ferrocyanide.

It is convenient to prepare a solution of which 1 cc. corresponds approximately to 0.01 grm. of zinc by dissolving 45 grm. of the pure salt in a litre of water. This solution is standardised as follows : 2.5 grm. of pure zinc are dissolved in 25 cc. of hydrochloric acid (1 : 1) and the solution diluted to 250 cc. 25 cc. of this standard zinc solution is withdrawn, diluted to 200 cc., 5 grm. of ammonium chloride and 10 cc. of concentrated hydrochloric acid added, and the solution heated to 80°C Ferrocyanide solution is added until a drop of the liquid gives a brown coloration with a saturated solution of uranium acetate on a spot plate. The precipitation of the zinc ferrocyanide does not take place immediately; hence the solution must be allowed to stand for one minute, the spot test repeated, and further ferrocyanide solution added if necessary.

(3) Sodium Sulphide.

5-6 grm. of sodium sulphide (" rock " or " concentrated," *i.e.,* 60% Na_2S) or 10-12 grm. of sodium sulphide " crystals " are dissolved in approximately 200 cc. water, allowed to stand overnight, and then filtered, and the solution made up to 250 cc.

A standard zinc solution is prepared by dissolving 57·5 grm. of zinc sulphate (crystals, $7H_2O$) in water or by dissolving 13·07 grm. pure metallic zinc in dilute hydrochloric acid, treating the solution with ammonia until the precipitate which forms just dissolves, and diluting to a litre.

The sulphide solution is standardised by titrating 50 cc. with the zinc solution, using a dilute solution of nickel sulphate on a spot-plate as an external indicator. A black or grey precipitate will be shown until all the sulphide is precipitated as zinc sulphide.

The sulphide solution is used for the determination of zinc, copper, nickel, and cobalt, whilst the zinc solution may be used for the determination of sodium sulphide.

FACTORS FOR QUANTITATIVE ANALYSIS.

Calculated from International Atomic Weights, 1917.

Weighed as.	Required.	Factor.	Log
Aluminium.			
Al_2O_3	Al	0.53034	$\bar{1}$.72455
	$AlCl_3$	2.61220	0.41700
$AlPO_4$	Al_2O_3	0.41837	$\bar{1}$.62156
Ammonium			
NH_4Cl	NH_3	0.31836	$\bar{1}$.50292
	NH_4	0.33702	$\bar{1}$.52766
	NH_4OH	0.65489	$\bar{1}$.81617
$(NH_4)_2PtCl_6$	NH_3	0.07673	$\bar{2}$.88494
	NH_4	0.08123	$\bar{2}$.90968
	N	0.06311	$\bar{2}$.80007
	NH_4Cl	0.24095	$\bar{1}$.38193
Pt	NH_3	0.17452	$\bar{1}$.24186
	NH_4	0.18475	$\bar{1}$.26660
	N	0.14355	$\bar{1}$.15699
	NH_4Cl	0.54809	$\bar{1}$.73885
$(NH_4)_2SO_4$	NH_3	0.25781	$\bar{1}$.41130
Antimony.			
Sb_2O_3	Sb	0.83354	$\bar{1}$.92093
	Sb_2S_3	1.16705	0.06709
	SbO_3	1.16643	0.06686
Sb_2O_4	Sb	0.78975	$\bar{1}$.89749
	Sb_2O_3	0.94746	$\bar{1}$.97656
	Sb_2O_5	1.05255	0.02225
Sb_2O_5	Sb	0.75031	$\bar{1}$.87524
	Sb_2S_3	1.05050	0.02140
	Sb_2O_3	0.90015	$\bar{1}$.95431
Sb_2S_3	Sb	0.71424	$\bar{1}$.85384
	Sb_2O_3	0.85686	$\bar{1}$.93291
	Sb_2O_5	0.95192	$\bar{1}$.97860
$NaH_2Sb_2O_7$	SbO_3	0.84365	$\bar{1}$.92617
	Sb_2O_3	0.72026	$\bar{1}$.85749
	Sb_2O_5	0.80017	$\bar{1}$.90318

Factors for Quantitative Analysis—*(continued)*.

Weighed as.	Required.	Factor	Log.
Arsenic.			
As_2S_3	As	0.60918	$\bar{1}.78475$
	As_2O_3	0.80423	$\bar{1}.90538$
	As_2O_5	0.93426	$\bar{1}.97047$
	AsO_4	1.12930	0.05281
As_2O_3	As	0.75746	$\bar{1}.87937$
	AsO_3	1.24243	0.09431
	As_2O_5	1.16170	0.06509
	AsO_4	1.40420	0.14743
As_2O_5	As	0.65204	$\bar{1}.81428$
	As_2O_3	0.86082	$\bar{1}.93491$
	AsO_3	1.06960	0.02922
	AsO_4	1.20875	0.08234
$Mg_2As_2O_7$	As_2O_3	0.63731	$\bar{1}.80435$
	As_2O_5	0.74035	$\bar{1}.86944$
	AsO_4	0.89492	$\bar{1}.95178$
	As_2S_3	0.79246	$\bar{1}.89897$
	As_2S_5	0.99869	$\bar{1}.99943$
	AsO_7	0.79187	$\bar{1}.89866$
Barium.			
$BaSO_4$	Ba	0.58848	$\bar{1}.76973$
	BaO	0.65701	$\bar{1}.81758$
	$BaCl_2$	0.89230	$\bar{1}.95051$
$BaCO_3$	Ba	0.69598	$\bar{1}.84260$
	BaO	0.77706	$\bar{1}.89045$
	$BaCl_2$	1.05533	0.02338
BaO	Ba	0.89568	$\bar{1}.95215$
$BaCrO_4$	Ba	0.54216	$\bar{1}.73413$
	BaO	0.60531	$\bar{1}.78198$
	$BaCl_2$	0.82207	$\bar{1}.91491$
$BaSiF_6$	Ba	0.49118	$\bar{1}.69124$
	BaO	0.54839	$\bar{1}.73909$
$BaCl_2$	Ba	0.65951	$\bar{1}.81922$
	BaO	0.73633	$\bar{1}.86707$
Bismuth.			
Bi_2O_3	Bi	0.89654	$\bar{1}.95257$
Bi_2S_3	Bi	0.81221	$\bar{1}.90967$
	Bi_2O_3	0.90594	$\bar{1}.95710$
Boron.			
B_2O_3	B	0.31429	$\bar{1}.49733$
Bromine.			
AgBr	Br	0.42556	$\bar{1}.62896$
	HBr	**0.43092**	**$\bar{1}.63440$**

Factors for Quantitative Analysis—*(continued)*.

Weighed as.	Required.	Factor.	Log.
Cadmium.			
CdO	Cd	0.87540	$\bar{1}$.94221
	CdS	1.12510	0.05119
CdS	Cd	0.77807	$\bar{1}$.89102
	CdO	0.88882	$\bar{1}$.94881
Calcium.			
CaO	Ca	0.71465	$\bar{1}$.85409
	$CaCl_2$	1.97945	0.29655
$CaSO_4$	Ca	0.29435	$\bar{1}$.46886
	CaO	0.41188	$\bar{1}$.61477
	$CaCl_2$	0.81530	$\bar{1}$.91132
$CaCO_3$	Ca	0.40041	$\bar{1}$.60250
	CaO	0.56029	$\bar{1}$.74841
	$CaCl_2$	1.10907	0.04496
CO_2	$CaCO_3$	2.27415	0.35682
Carbon			
CO_2	C	0.27280	$\bar{1}$.43586
	CO_3	1.36360	0.13469
$CaCO_3$	CO_2	0.43972	$\bar{1}$.64318
	CO_3	0.59962	$\bar{1}$.77787
$BaCO_3$	CO_2	0.22295	$\bar{1}$.34821
	CO_3	0.30402	$\bar{1}$.48290
Chlorine.			
AgCl	Cl	0.24738	$\bar{1}$.39337
	HCl	0.25442	$\bar{1}$.40555
	ClO_3	0.58225	$\bar{1}$.76511
	ClO_4	0.69388	$\bar{1}$.84128
	NaCl	0.40784	$\bar{1}$.61049
	KCl	0.52016	$\bar{1}$.71614
	$NaClO_3$	0.74270	$\bar{1}$.87081
	$KClO_3$	0.85502	$\bar{1}$.93198

Factors for Quantitative Analysis—*(continued)*.

Weighed as.	Required	Factor.	Log.
Chromium.			
Cr_2O_3	Cr	0.68422	$\bar{1}.83519$
	CrO_3	1.31580	0.11919
	CrO_4	1.52635	0.18365
	Cr_2O_7	1.42106	0.15261
$BaCrO_4$	Cr	0.20523	$\bar{1}.31224$
	CrO_3	0.39467	$\bar{1}.59624$
	CrO_4	0.45782	$\bar{1}.66070$
	Cr_2O_3	0.29995	$\bar{1}.47706$
	Cr_2O_7	0.42626	$\bar{1}.62967$
$PbCrO_4$	Cr	0.16079	$\bar{1}.20653$
	CrO_3	0.30941	$\bar{1}.49053$
	CrO_4	0.35892	$\bar{1}.55499$
	Cr_2O_3	0.23515	$\bar{1}.37134$
	Cr_2O_7	0.33416	$\bar{1}.52395$
$K_2Cr_2O_7$	Cr	0.35350	$\bar{1}.54839$
	Cr_2O_3	0.51666	$\bar{1}.71320$
	CrO_3	0.67981	$\bar{1}.83239$
	CrO_4	0.78859	$\bar{1}.89685$
	Cr_2O_7	0.73420	$\bar{1}.86581$
Cobalt.			
Co	CoO	1.27131	0.10426
CoO	Co	0.78658	$\bar{1}.89574$
$CoSO_4$	Co	0.38038	$\bar{1}.58022$
	CoO	0.48359	$\bar{1}.68448$
$K_3Co(NO_2)_6$	Co	0.13037	$\bar{1}.11517$
	CoO	0.16574	$\bar{1}.21943$
Copper.			
CuO	Cu	0.79892	$\bar{1}.90250$
Cu_2S	Cu	0.79864	$\bar{1}.90235$
	CuO	0.99963	$\bar{1}.99984$
	Cu_2O	0.89913	$\bar{1}.95382$
Cyanogen.			
Ag	CN	0.24115	$\bar{1}.38228$
AgCN	CN	0.19429	$\bar{1}.28845$
	HCN	0.20173	$\bar{1}.30497$
Fluorine.			
CaF_2	F	0.48675	$\bar{1}.68730$
	HF	0.51258	$\bar{1}.70976$
$BaSiF_6$	F	0.40762	$\bar{1}.61025$
	HF	0.42924	$\bar{1}.63270$
	H_2SiF_6	0.51602	$\bar{1}.71267$
	KF	0.41513	$\bar{1}.61818$

Factors for Quantitative Analysis—(continued).

Weighed as.	Required.	Factor.	Log.
Gold.			
Au	$AuCl_3$	1.53943	0.18736
	Au_2O_3	1.12170	0.04988
Hydrogen.			
H_2O	H	0.11192	$\bar{1}.04884$
Iodine.			
I_2O_5	I	0.76037	$\bar{1}.88102$
	HI	0.76638	$\bar{1}.88445$
AgI	I	0.54054	$\bar{1}.73283$
	HI	0.54482	$\bar{1}.73626$
PdI_2	I	0.70402	$\bar{1}.84760$
	HI	0.70964	$\bar{1}.85103$
Iron.			
Fe_2O_3	Fe	0.69939	$\bar{1}.84472$
Lead.			
PbO	Pb	0.92833	$\bar{1}.96770$
PbO_2	Pb	0.86622	$\bar{1}.93763$
PbS	Pb	0.86580	$\bar{1}.93742$
	PbO	0.93265	$\bar{1}.96972$
	$PbSO_4$	1.26720	0.10285
$PbCl_2$	Pb	0.74500	$\bar{1}.87216$
$PbSO_4$	Pb	0.68323	$\bar{1}.83457$
	PbO	0.73599	$\bar{1}.86687$
	PbS	0.78914	$\bar{1}.89715$
Lithium			
Li_2CO_3	Li	0.18786	$\bar{1}.27383$
Li_3PO_4	Li	0.17970	$\bar{1}.25454$
	LiCl	1.09785	0.04055
	Li_2O	0.38684	$\bar{1}.58753$
Magnesium.			
MgO	Mg	0.60317	$\bar{1}.78044$
$Mg_2P_2O_7$	Mg	0.21839	$\bar{1}.33923$
	MgO	0.36207	$\bar{1}.55879$
	$MgSO_4$	1.08100	0.03383
$MgSO_4$	Mg	0.20203	$\bar{1}.30540$
	MgO	0.33493	$\bar{1}.52496$
Manganese.			
MnO	Mn	0.77442	$\bar{1}.88898$
Mn_3O_4	Mn	0.72027	$\bar{1}.85749$
	MnO	0.93026	$\bar{1}.96851$
	MnO_4	1.55933	0.19297
MnS	Mn	0.63145	$\bar{1}.80033$
	MnO	0.81538	$\bar{1}.91136$
	MnO_4	1.36717	0.13582
$MnSO_4$	Mn	0.36380	$\bar{1}.56986$
	MnO	0.46977	$\bar{1}.67188$

Factors for Quantitative Analysis—(continued).

Weighed as.	Required.	Factor.	Log.
Mercury.			
Hg	HgO	1.07977	0.03333
	HgS	1.15983	0.06439
	Hg_2O	1.03980	0.01696
	Hg_2Cl_2	1.17667	0.07069
HgO	Hg	0.92613	$\bar{1}.96667$
	HgS	1.07415	0.03106
HgS	Hg	0.86220	$\bar{1}.93561$
Hg_2Cl_2	Hg	0.84977	$\bar{1}.92931$
	HgO	0.91757	$\bar{1}.96264$
Molybdenum			
MoS_3	Mo	0.49952	$\bar{1}.69856$
	MoO_2	0.66605	$\bar{1}.82350$
MoO_2	Mo	0.75000	$\bar{1}.87506$
Nickel.			
NiO	Ni	0.78575	$\bar{1}.89529$
$NiSO_4$	Ni	0.37922	$\bar{1}.57889$
	NiO	0.48261	$\bar{1}.68360$
$(C_4H_7O_2N_2)_2Ni$			
(Dimethylglyoxime ppt.)	Ni	0.20311	$\bar{1}.30777$
$(C_{14}H_{11}O_2N_2)_2Ni$			
(α-Benzildioxime ppt.)	Ni	0.10927	$\bar{1}.03848$
Nitrogen.			
(See also *Ammonium*.)			
$(NH_4)_2PtCl_6$	N	0.06310	$\bar{1}.80005$
	NO_3	0.27930	$\bar{1}.44607$
Pt	N	0.14355	$\bar{1}.15699$
	NO_3	0.63535	$\bar{1}.80301$
Palladium.			
PdI_2	Pd	0.29594	$\bar{1}.47120$
Phosphorus.			
P_2O_5	P	0.43694	$\bar{1}.64042$
	PO_4	1.33783	0.12640
$Mg_2P_2O_7$	P	0.27873	$\bar{1}.44519$
	PO_4	0.85343	$\bar{1}.93117$
	P_2O_5	0.63793	$\bar{1}.80477$
	P_2O_7	0.78161	$\bar{1}.89299$
	PO_3	0.70978	$\bar{1}.85112$
Phosphomolybdate ppt.	P	0.01640	$\bar{2}.21484$
	P_2O_5	0.03753	$\bar{2}.57438$
	$Ca_3(PO_4)_2$	0.08196	$\bar{2}.91360$

Factors for Quantitative Analysis—*(continued)*.

Weighed as.	Required.	Factor.	Log.
Platinum.			
$(NH_4)_2PtCl_6$	Pt	0.43960	$\bar{1}.64306$
	$PtCl_4$	0.75904	$\bar{1}.88026$
	$PtCl_6$	0.91875	$\bar{1}.96319$
Pt	$PtCl_4$	1.72663	0.23720
	$PtCl_6$	2.08990	0.32013
K_2PtCl_6	Pt	0.40151	$\bar{1}.60370$
	$PtCl_4$	0.69327	$\bar{1}.84090$
	$PtCl_6$	0.83914	$\bar{1}.92383$
Potassium			
KCl	K	0.52441	$\bar{1}.71967$
K_2SO_4	K	0.44875	$\bar{1}.65201$
	K_2O	0.54056	$\bar{1}.73285$
	KCl	0.85574	$\bar{1}.93234$
KNO_3	K	0.38672	$\bar{1}.58739$
K_2PtCl_6	K	0.16085	$\bar{1}.20643$
	K_2O	0.19376	$\bar{1}.28727$
	KCl	0.30674	$\bar{1}.48676$
	K_2CO_3	0.28428	$\bar{1}.45375$
$KClO_4$	K	0.28219	$\bar{1}.45054$
	KCl	0.53811	$\bar{1}.73087$
$K_2NaCo(NO_2)_6.H_2O$	K	0.17215	$\bar{1}.23591$
Silicon.			
SiF_4	SiO_2	0.57815	$\bar{1}.76204$
SiO_2	Si	0.46932	$\bar{1}.67147$
	SiO_3	1.26533	0.10220
	SiO_4	1.53066	0.18488
$BaSiF_6$	H_2SiF_6	0.51602	$\bar{1}.71267$
	SiO_2	0.21561	$\bar{1}.33367$
	SiF_4	0.37294	$\bar{1}.57163$
Silver.			
AgCl	Ag	0.75262	$\bar{1}.87657$
AgBr	Ag	0.57444	$\bar{1}.75924$
AgI	Ag	0.45945	$\bar{1}.66224$
AgCN	Ag	0.80572	$\bar{1}.90618$
Ag	AgCl	1.32870	0.12343
	AgBr	1.74085	0.24076

Factors for Quantitative Analysis—*(continued)*.

Weighed as.	Required.	Factor.	Log.
Sodium.			
Na$_2$O	Na	0.74194	$\bar{1}$.87037
NaCl	Na	0.39344	$\bar{1}$.59487
	Na$_2$O	0.53029	$\bar{1}$.72451
Na$_2$SO$_4$	Na	0.32381	$\bar{1}$.51029
	Na$_2$O	0.43644	$\bar{1}$.63992
	NaCl	0.82392	$\bar{1}$.91541
Na$_2$H$_2$Sb$_2$O$_7$	Na	0.11488	$\bar{1}$.06025
	Na$_2$O	0.15484	$\bar{1}$.18988
	NaCl	0.29200	$\bar{1}$.46537
Na$_2$CO$_3$	Na	0.43395	$\bar{1}$.63743
	Na$_2$O	0.58487	$\bar{1}$.76706
Strontium.			
SrSO$_4$	Sr	0.47706	$\bar{1}$.67857
	SrO	0.56417	$\bar{1}$.75141
SrO	Sr	0.84560	$\bar{1}$.92716
SrCO$_3$	Sr	0.59356	$\bar{1}$.77346
	SrO	0.70194	$\bar{1}$.84630
Sulphur.			
BaSO$_4$	S	0.13734	$\bar{1}$.13780
	SO$_2$	0.27443	$\bar{1}$.43843
	SO$_3$	0.34297	$\bar{1}$.53526
	SO$_4$	0.41151	$\bar{1}$.61438
	S$_2$O$_3$	0.24016	$\bar{1}$.38049
	H$_2$SO$_4$	0.42023	$\bar{1}$.62349
	Na$_2$SO$_4$	0.60858	$\bar{1}$.78432
	H$_2$S	0.14598	$\bar{1}$.16429
CdS	S	0.22193	$\bar{1}$.34621
	H$_2$S	0.23589	$\bar{1}$.37270
Tin.			
SnO$_2$	Sn	0.78766	$\bar{1}$.89634
	SnCl$_2$	1.25830	0.09978
Titanium.			
TiO$_2$	Ti	0.60051	$\bar{1}$.77852
Tungsten			
WO$_3$	W	0.79310	$\bar{1}$.89933
Uranium.			
U$_3$O$_8$	U	0.84808	$\bar{1}$.92844
K$_2$U$_2$O$_7$	U	0.71467	$\bar{1}$.85410
Vanadium.			
V$_2$O$_5$	V	0.56044	$\bar{1}$.74853
Zinc.			
ZnO	Zn	0.80339	$\bar{1}$.90492
	ZnS	1.19737	0.07823
ZnS	Zn	0.67088	$\bar{1}$.82664
	ZnO	0.83516	$\bar{1}$.92177

GAS ANALYSIS.

In the qualitative examination of a gas the first observations are of colour, odour, combustibility, and ability to support combustion. Then it is ascertained whether the gas or part of it can be removed by certain absorbents. The unabsorbed gas is mixed with oxygen (or possibly hydrogen) and burnt; the product of this combustion is again treated with absorbents. If the gas is completely unabsorbed and incombustible it must consist of nitrogen and (or) some member of the argon group. Nitrogen combines with, and so may be removed by, metallic magnesium at a high temperature, or lithium at a low red heat.

REACTIONS OF GASES.

Acetylene.	Absorbed by Br water. Forms brick red ppt. with Cu_2Cl_2.
Ammonia.	Very soluble in water. Expelled from its aqueous solution on boiling. Absorbed by H_2SO_4.
Boron chloride.	Absorbed by water or KOH.
Boron fluoride.	Chars paper. Very soluble in water.
Carbon disulphide.	Absorbed by alcoholic KOH.
Carbon dioxide.	Absorbed by KOH or soda lime.
Carbon monoxide.	Absorbed by Cu_2Cl_2 in hydrochloric acid or ammoniacal solution.
Chlorine.	Soluble in water. Removed by KOH or mercury.
Cyanogen.	Soluble in water (1 vol. dissolves $4\frac{1}{2}$ vols.), alcohol (1 vol. dissolves 23 vols.) and absorbed by moist alkalies.
Cyanogen chloride.	Soluble in water (1 vol. dissolves 25 vols.), more so in alcohol. Absorbed by KOH.
Ethylene.	Absorbed by fuming H_2SO_4, Br water, or Cu_2Cl_2 solution.
Hydrogen.	Absorbed by palladium.
Hydrogen chloride, bromide or iodide.	Absorbed by water, KOH, or powdered borax.
Hydrogen cyanide.	Absorbed by water, alkalies, or mercuric oxide.
Hydrogen phosphide.	Slowly absorbed by $CuSO_4$ soln. Decomposed by Br or fuming H_2SO_4.
Hydrogen silicide.	Decomposed by KOH, 1 vol. giving 4 vols. H_2.
Hydrogen sulphide.	Soluble in water and KOH. Darkens lead acetate paper. Decomposed by Br or conc. H_2SO_4.
Methane.	Insoluble in water. Burns with faintly luminous flame.
Methyl, ethyl amines.	See ammonia.
Methyl chloride.	Soluble in water (1 vol. dissolves 4 vols.). Very soluble in alcohol.
Methyl ether.	Soluble in water (1 vol. dissolves 32 vols. at 10°) and H_2SO_4; very soluble in alcohol.

Nitric oxide.	Absorbed by Br water or FeSO₄ soln. Combines with oxygen giving nitrogen peroxide, which can then be absorbed by KOH.
Nitrous oxide.	With an equal vol. of hydrogen, gives an explosive mixture, leaving an equal vol. of nitrogen. Soluble in alcohol and water.
Nitrogen.	Insoluble. Combines at red heat with titanium, magnesium, and lithium.
Oxygen.	Absorbed by alkaline pyrogallol, phosphorus, cuprous chloride, or sodium hydrosulphite soln.
Silicon fluoride.	Absorbed and decomposed by water, with separation of gelatinous silicic acid.
Sulphur dioxide.	Soluble in water. Absorbed by KOH. dry PbO₂ and MnO₂.

EXAMINATION OF A GAS.

The gas is tested for colour, smell, and combustibility. It is then sparked, and note is taken of any change in volume, the formation of any coloured gas (*e.g.*, NO₂ from nitrogen and oxygen), or of any deposition of carbon, phosphorus, arsenic, sulphur, silica, etc.

A. If the gas is not combustible it is treated with strong potash solution.

I. No appreciable absorption :
(*a*) Gas ignites a glowing splinter of wood.

Odourless, absorbed by alkaline pyrogallol, or sodium hydrosulphite soln.	Oxygen.
Peculiar odour, shows reactions of oxygen, attacks mercury, decomposes potassium iodide.	Ozone.
Odourless, unabsorbed by pyrogallol, fairly soluble in cold water and absolute alcohol.	Nitrous oxide.

(*b*) Gas does not support combustion.

Absorbed by ferrous sulphate solution, gives red fumes when mixed with air.	Nitric oxide.
No positive reactions.	Nitrogen.

II. Absorption.

First note whether the gas will dissolve in water alone—ammonia, hydrochloric hydrobromic, or hydriodic acid, boron fluoride, silicon fluoride.

(*a*) The gas is of a yellow colour, and attacks mercury.

Greenish yellow, strong smell, attacking the mucous membrane.	Chlorine.
Yellow, fairly soluble in water, explosive.	Chlorine monoxide
Greenish yellow, very explosive.	Chlorine dioxide.

(*b*) Yellowish red.

Absorbed by ferrous sulphate solution, conc. H$_2$SO$_4$, and by water, with which it forms nitric and nitrous acids, and nitric oxide.	Nitrogen peroxide

(*c*) Reddish brown.

Odour similar to, but stronger than, that of chlorine	Bromine.

(*d*) Colourless.

Strong smelling, reacts alkaline with litmus, very soluble in water, white fumes with hydrochloric acid.	Ammonia.
Sharp smell, reacts acid, soluble in water, turns dichromate paper green.	Sulphur dioxide
Soluble in its own volume of water, gives with lime water a white ppt. soluble with excess of carbon dioxide.	Carbon dioxide
Strong smell, decomposed slowly by water.	Cyanogen chloride

(*e*) Colourless, acid reaction, white fumes with ammonia.

Decomposed by chlorine with separation of iodine or iodine monochloride.	Hydriodic acid.
Decomposed by chlorine with formation of bromine.	Hydrobromic acid.
Not decomposed by chlorine.	Hydrochloric acid
Attacks glass.	Hydrofluoric acid
Absorbed by water with separation of gelatinous silicic acid.	Silicon fluoride.
Gives dense fumes in the air, chars paper, very soluble in water, absorbed by turpentine.	Boron fluoride.

B. The gas is combustible.

Burns with a scarcely visible blue flame, forming water.	Hydrogen.
Bright blue flame, product carbon dioxide.	Carbon monoxide.
Blue flame, separation of sulphur on cold surface, and formation of acids containing sulphur.	Hydrogen sulphide, carbon oxysulphide or disulphide.
Red flame, separation of brown selenium.	Hydrogen selenide.
Brilliant yellow flame, formation of phosphoric acid, or deposition of phosphorus, often burns spontaneously.	Phosphine.
Bluish white flame, deposition of white arsenious oxide or brown arsenic.	Arsine.
Red flame, deposition of white silica or brown silicon, often burns spontaneously.	Hydrogen silicide
Faintly luminous flame, formation of water and carbon dioxide.	Methane.

After this test the gas is treated with caustic potash solution.

I. Absorption.

Soluble in water, can be expelled from solution by warming with potash, gas and solution smell like ammonia, alkaline reaction, dense fumes with hydrochloric acid, and a ppt. with platinic chloride.	Methyl and similar amines.
Soluble in water, soluble in alcohol and ether.	Methyl ether

Gas dissolves slowly in water :

1. Combustible with blue flame, sulphur and sulphur dioxide resulting, bad odour, ppts. many metals from their salt solutions.	Hydrogen sulphide.
2. Bad odour, brown selenium separates on burning.	Hydrogen selenide.
3. Burns with separation of tellurium.	Hydrogen telluride.
4. Burns with purple red flame, no water formed.	Cyanogen.

II. No absorption either by water or caustic potash solution.

Volume of gas quadruples on treatment with potash, burns depositing silica and brown silicon.	Hydrogen silicide.
Burns with blue flame, producing carbon dioxide but no water, absorbed by cuprous chloride.	Carbon monoxide
Burns forming water only.	Hydrogen.

Combustion results in separation of stable body, aqueous solution of which reacts acid; gives black ppt. with copper sulphate :

1. Fishy odour, often spontaneously combustible, giving red phosphorus and phosphorus pentoxide, absorbed by acid cuprous chloride.	Phosphine.
2. Peculiar odour, burns to arsenious oxide, and deposits arsenic, absorbed by acid cuprous chloride, giving black ppt.	Arsine.

Burns to water and carbon dioxide, sometimes with separation of carbon :

1. Unabsorbed by sulphuric acid, bromine, or ammoniacal cuprous chloride, slightly soluble in absolute alcohol.	Paraffin hydrocarbons.
2. Burns with a luminous flame, unabsorbed by cuprous chloride, absorbed by bromine or fuming sulphuric acid. Very slowly absorbed by concentrated sulphuric acid.	Ethylene.
3. As ethylene, but easily absorbed by sulphuric acid.	Propylene, butylene.
4. Burns with smoky flame, absorbed by bromine, and by ammoniacal cuprous chloride, giving a red ppt.	Acetylene.

5. As acetylene, but giving yellow ppt. with cuprous chloride.	Allylene.
6. Burns with green mantled flame.	Methyl chloride, ethyl chloride or fluoride.

ANALYSIS OF GAS-MIXTURES.

Correction for temperature and pressure. See Physico-Chemical Constants section.

Absorbents.

Potash.	400 grm. KOH dissolved in 1 litre of water.
Bromine.	Dissolved in a 5 per cent. solution of KBr until a fairly deep colour is obtained.
Pyrogallol.	10 gms. pyrogallol dissolved in 25 to 30 cc. water. *When required for use* one part of this solution is mixed with five times its volume of potash solution.
Cuprous chloride.	(i) Ammoniacal. Mix together 50 grm cuprous chloride and 25 grm. ammonium chloride, add 150 cc. water and pass in ammonia gas, shaking at frequent intervals until solution is complete.
	(ii) Hydrochloric acid. Dissolve 25 grm black copper oxide in concentrated hydrochloric acid, add 30 grm. copper, and boil under a reflux condenser until colourless. Dilute to 500 cc. with conc. hydrochloric acid.

ESTIMATION OF CARBON DIOXIDE AND CARBON MONOXIDE IN AIR.

Carbon dioxide. The carbon dioxide from a known volume of air is absorbed by means of a standard baryta solution, and the excess baryta is titrated with oxalic acid, using phenolphthalein as indicator (Pettenkofer).

Required : (i) Soln. of oxalic acid, 5·63 grm. per litre, of which 1 cc. = 1 cc. CO_2; (ii) soln. of 200 grm. $Ba(OH)_2$ and 10 grm. $BaCl_2$ per litre; (iii) dilute baryta soln. containing 30 cc. of former soln. to 1000 cc. The strength of this last solution is determined by placing in a small flask nearly sufficient oxalic acid to neutralise 10 cc. baryta, then adding the baryta and neutralising by slowly running in more oxalic acid. By this means an accurate standardisation is made possible, as the solution is never so strongly alkaline as to absorb appreciable amounts of carbon dioxide from the air.

For the estimation of carbon dioxide, thick-walled conical Erlenmeyer flasks are used. They are furnished with double-

bored rubber stoppers, the holes in which are closed by short pieces of glass rod. The content of each flask is measured up to the point to which the rubber stopper reaches, and is marked on the outside of the flask. The simplest way of obtaining a sample of the air is to fill a flask with water, and empty it in the room, the air of which is to be tested. By means of a pipette 10 cc. baryta is run into the flask, the glass rods being removed from the holes in the stopper, and the point of the pipette being inserted through one of them. The flask is now stoppered up again, and should be shaken at intervals during half an hour, after which the glass rods are again removed, phenolphthalein is added, and oxalic acid is run in from a burette until the solution is colorless.

The difference between the titrations of fresh baryta and that in the flask gives the carbon dioxide content in cc. (Hesse's Method; for further details see Hempel, *Gas Analysis*.)

Carbon monoxide. In small quantities (less than 1 per cent.) carbon monoxide can only be accurately estimated by means of blood, or by some oxidation method.

(i) Hæmoglobin, the colouring matter of blood, unites with oxygen and carbon monoxide, and the carbon monoxide compound dissociates less readily than the oxy-compound. The proportion of oxy-hæmoglobin to carbon monoxide hæmoglobin will be the ratio of the partial pressures of the gases in the mixture.

If the oxygen content of the air is known, the amount of carbon monoxide can readily be calculated if the proportion between oxy-hæmoglobin and carbon monoxide hæmoglobin in the blood is determined. This can be done colorimetrically, using a solution containing 1 gm. of carmine with a few drops of ammonia in 100 cc. glycerine diluted with water to 1 litre. A dilute solution of oxy-hæmoglobin is yellow, one of carbon monoxide hæmoglobin is rose-red.

A sample of air is taken by filling a flask of 250 cc. capacity with water and emptying it in the room. Now 5 cc. of a 5 per cent. aqueous solution of defibrinated ox-blood is run in, the bottle is stoppered up, and shaken for some minutes. The liquid is then brought into one of three exactly equal test tubes. The second tube contains 5 cc. of blood solution, and the third the same quantity saturated with carbon monoxide. To the first and second tubes carmine solution is added until the solutions have attained the same degree of colour as that of the liquid in the third tube. Then if x and y cc. are amounts of carmine solution added to the first and second tubes respectively, and S is the per cent. saturation

T

of the blood which was shaken with the air,

$$\frac{x}{x+5} \times \frac{y+5}{y} \times 100 = S$$

From the following table the content of carbon monoxide in the air can be obtained :

S.	10	20	30	40	50	60	70	80	90
CO per cent.	0.015	0.04	0.08	0.12	0.16	0.22	0.30	0.60	1.2

If the air contains more than 1 per cent. carbon monoxide the estimation is preferably carried out by absorption with cuprous chloride.

(ii) An oxidation method for the estimation of small quantities of carbon monoxide was described by Kinnicutt and Sandford (*J. Amer. Chem. Soc.*, 1900, 22, [1], 14–18; *J.S.C.I.*, 1900, 19, 275–276).

Good results were obtained by oxidising with iodine pentoxide, and titrating the liberated iodine with N/1000 sodium thiosulphate. The iodine pentoxide was contained in a small U-tube which could be heated to 150°C. by means of an oil-bath. This tube was connected to an absorption tube containing potassium iodide solution, and 250 cc. to 1000 cc. of gas was passed through, unsaturated hydrocarbons, hydrogen sulphide, sulphur dioxide and other reducing gases being removed before coming into contact with the iodine pentoxide. It was found that the presence of other constituents of coal gas had no effect, and the method is available for the determination of 0·0025 per cent. of carbon monoxide in air.

COAL GAS AND FUEL GASES.

Coal gas consists mainly of hydrogen, carbon monoxide, paraffins, chiefly methane, unsaturated hydrocarbons, vapours of benzene, toluene, etc. In addition there are usually present small quantities of carbon dioxide, oxygen, nitrogen, and sulphur compounds.

The various constituents are determined in the following order : Carbon dioxide by absorption with strong potash solution, benzene and unsaturated hydrocarbons by fuming sulphuric acid, oxygen by alkaline pyrogallol, and carbon monoxide by ammoniacal or hydrochloric acid cuprous chloride. Paraffins, hydrogen and nitrogen if necessary, remain to be determined by eudiometric combustion with excess air or oxygen. The contraction is noted, and the carbon dioxide formed is absorbed by potash. This absorption is equal to the volume of methane, as methane burns forming its own volume of carbon dioxide.

Then if C=contraction, and A=absorption, volume of

methane = A. Contraction due to methane = 2A, so contraction due to hydrogen = C − 2A, and volume of hydrogen = 2/3 (C − 2A). Nitrogen is obtained by difference.

It should be mentioned that the gas estimated as methane usually contains a small amount of ethane and possibly propane.

Total sulphur is usually determined by the "Referees' Method." A known volume of gas is burned at the rate of about 0·5 cu. ft. an hour in a small Bunsen burner, and the products of combustion together with some ammonia which is evaporated at the same time are passed upwards through a condensing tower filled with glass marbles to break up the stream of gas.

Bromine water or nitric acid may be allowed to trickle over these marbles, and all the sulphur is then obtained as a solution of ammonium sulphate at the bottom of the condenser. Barium chloride is added and the precipitated barium sulphate is filtered, ignited and weighed.

FIRE-DAMP.

Fire-damp is essentially a mixture of methane with air. Its explosiveness is greatest when the methane amounts to about 9.5 per cent., the oxygen of the air then being just sufficient for the combustion of the methane. Mixtures containing under 5 or over 14 per cent. methane are not inflammable, but are nevertheless dangerous, especially if coal dust is present

The Grisoumeter of Coquillon is used for the determination of methane in fire-damp. A measured volume of the gas, after absorption of carbon di- and monoxides, is mixed with a suitable quantity of oxygen, and led either through a thin platinum tube (internal diameter about 1 mm.) heated by a Méker burner, as in some modifications of the Orsat apparatus, or over a spiral of platinum wire heated to redness by an electric current. The gas then burns quietly.

In the Grisoumeter of Le Chatelier the amount of the gas is measured by observations of the pressure registered on a small manometer, the gas-volume remaining constant, and changes of temperature being avoided by surrounding the burette with a large quantity of water. The combustion tube is also the measuring tube and is connected to a mercury aspirator and a manometer.

Observations are taken of the manometer height h, barometric height H, and temperature of water t, and a flame is

initiated, a known volume of methane being added, if necessary, to make the mixture burn. Height of manometer h¹, and temperature of water t¹, are again taken. Then the methane in 100 vols. of gas mixture

$$= \tfrac{1}{2} \left(\frac{h - h^1}{H + h - h^1} - \frac{t - t^1}{t + 273} \right) \cdot \frac{t + 273}{t^1 + 273}$$

or approx. $\dfrac{h - h^1}{2(H + h - h^1)}$.

THE ORSAT APPARATUS.

This apparatus is widely used for the analysis of flue gases, exhaust gases and other similar mixtures. The burette A, which has a capacity of 100 cc., is made narrow at the lower end and graduated in 1/5 cc. A is situated in a glass cylinder containing water and is connected at the bottom to a small levelling bottle by means of a rubber tube. B, C and D are absorption vessels which in order to increase the surface are filled with glass tubes. Each of these bulbs is connected at the lower end with another equally large vessel which serves as a reservoir for the absorbent. The cocks b, c, d, are simple glass cocks which in order to avoid danger of breakage are best connected by means of rubber tubes; e is a three way cock, being drilled axially through the stopper in addition to the usual transverse boring. The tube f is filled with cotton wool in order to filter any dust from the incoming gas. By simply moving the cock e it is possible to connect f with A, the outer air with A or the outer air with f.

B is filled with caustic potash solution, C with alkaline pyrogallol, and D with cuprous chloride solution. E, which is connected to the capillary main by a platinum tube, contains water or glycerine and water, and is used in the estimation of combustible gases. The cocks b, c, d, are closed, and A is connected to the outer air by means of the three-way cock, e; by raising the levelling bottle F, the burette A is filled to the upper mark with water; e is then closed, the levelling bottle lowered, and a opened By this means B is filled with absorption solution. Similarly C and D are filled. The tube f can now be connected to the sample of gas to be analysed and by turning e so as to open to the outer air the tube can be washed with the gas sample by attaching a suction pump to the outlet. The three way cock is now turned to allow the passage of sample to A, which is filled with gas by means of the levelling bottle. This process is carried out twice to ensure the removal of air; e is then closed, a opened, and by means of F the gas is forced from A into B, where the carbon dioxide will be absorbed. The

process is now reversed and the gas returned to A. F is now adjusted until the levels of the water in A and F are the same when the volume of gas may be read on A. By subtracting this figure from the original volume (100 cc.) the volume of carbon dioxide absorbed is obtained. By the same means the
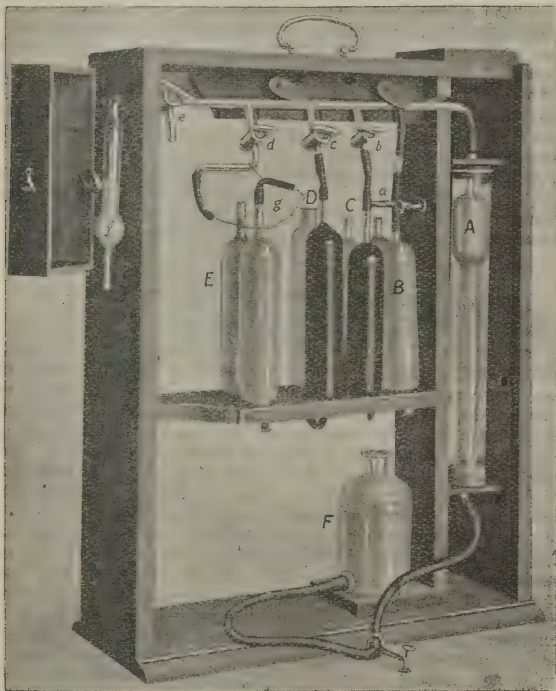
absorptions of gas in C and D yield the volume percentages of oxygen and carbon monoxide respectively. Care must be taken to avoid any of the absorption solutions passing into the horizontal capillary tubes.

For the estimation of methane and hydrogen 10 cc. of the

gas after the removal of absorbable constituents is made up to 100 cc. with air or oxygen. This mixture is passed slowly through the platinum tube g, heated to redness by a Méker burner, into the bulb E. In order to ensure complete combustion the gas should be passed through the heated platinum tube at least four times. It is then taken back into the burette A, and the contraction noted. The carbon dioxide produced by the combustion is estimated by absorption in potash. The amounts of methane and hydrogen can then be calculated as previously explained. Nitrogen is always estimated by difference. If it is required to determine unsaturated hydrocarbons the pyrogallol pipette may be disconnected at the rubber joint and temporarily replaced by one containing bromine water.

It should be remembered that after absorption with bromine water or cuprous chloride in hydrochloric acid the gas *must* be washed with potash before the reading is taken in A, as the vapour pressures of these absorbents are considerable.

THE HALDANE APPARATUS.

This apparatus is intended particularly for the analysis of air, but it is also useful for the determination of small quantities of methane or carbon monoxide in mine gases, etc. There are several modifications, full descriptions of which will be found in " Methods of Air Analysis " (J. S. Haldane). The diagram is of the form suited for use in a laboratory.

The gas is measured in the burette, A, which is about 800 mm. long. The upper wide part is of about 25 mm. bore, and has a capacity of 15 cc. The narrow part which is of about 3·5 mm. bore, is graduated to 0·01 cc. from 15 to 20 cc. The capacity is measured from the three-way tap, T, and does not include the bore. A water-jacket surrounds both the gas-burette and a compensation tube, B, the object of the latter being to nullify the effect of any changes of atmospheric pressure or temperature on the burette readings. One of the connections of the three-way tap is used for sampling, and the other is connected with the absorption pipettes, C and D, usually containing potash solution and alkaline pyrogallol respectively. The pyrogallol is protected from the atmosphere by potash solution in the bulbs, E and F. Before every burette reading the pressure should be adjusted by bringing the potash level to the mark, G, and using the pipette as a pressure gauge.

At the beginning of the analysis the tap, L, is opened to the atmosphere and by means of the levelling tube, K, and the
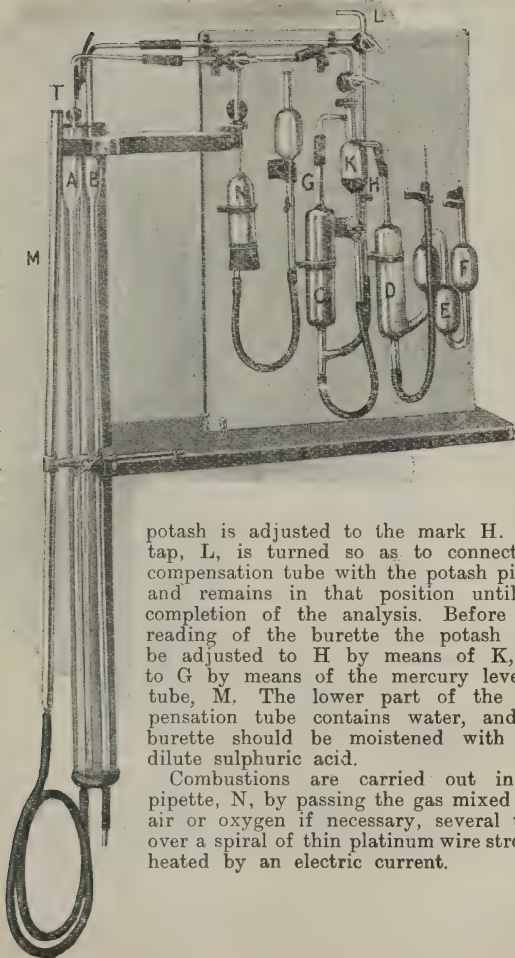
potash is adjusted to the mark H. The tap, L, is turned so as to connect the compensation tube with the potash pipette and remains in that position until the completion of the analysis. Before each reading of the burette the potash must be adjusted to H by means of K, and to G by means of the mercury levelling tube, M. The lower part of the compensation tube contains water, and the burette should be moistened with very dilute sulphuric acid.

Combustions are carried out in the pipette, N, by passing the gas mixed with air or oxygen if necessary, several times over a spiral of thin platinum wire strongly heated by an electric current.

BONE AND WHEELER APPARATUS.

There are several modifications of this apparatus; the diagram is of the form originally suggested for commercial gas analysis. (*J.S.C.I.*, 1908, **37**, 10.)
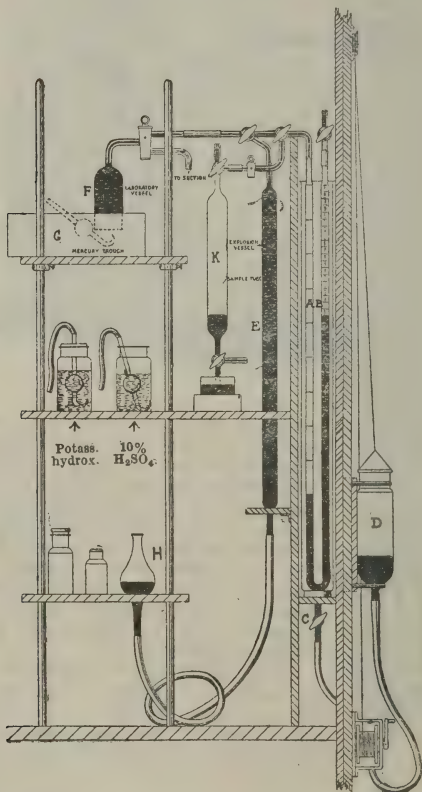
The apparatus consists of three main parts : (i) the measuring and pressure tubes, A and B surrounded by a water-jacket, and

connected to the mercury reservoir D ; (ii) the explosion tube, E, connected to a separate mercury reservoir, H, and fitted with platinum electrodes and leading wires to an induction coil ; (iii) the absorption vessel, F, standing over mercury in a wooden trough, G.

The gas is measured at constant volume, by means of the pressure which it exerts. For this purpose there is a series of "constant volume" marks in the measuring tube, A, each coinciding with a 100 mm. mark on the pressure tube, B.

The inner surfaces of the tubes, A and B, should be kept moist with dilute sulphuric acid. The moistening of A and B with the same liquid automatically eliminates the influence of water vapour on the measurements.

A small microscope is sometimes attached to facilitate the reading of the mercury level, and to avoid errors of parallax.

The gas for analysis may be introduced into the apparatus by means of the sampling tube, K, or simply from an ordinary test-tube under the wide end of the absorption vessel, F, which has been previously filled with mercury. Before measuring this gas the mercury level should be adjusted to the zero mark in A (by means of the reservoir, D, and the tap, C), and the reading taken in B. If this reading is not zero the necessary correction must be made on the reading of the sample of gas taken. It is very important that the mercury should be at the top of the pressure tube whenever any gas is admitted into the measuring tube.

The amount of gas originally taken should be as large as possible. Absorbable gases are removed in the laboratory vessel, F, 2 to 5 cc. of the absorbent being introduced by means of a suitably shaped pipette from below the surface of the mercury in the trough. After each absorption the gas is returned to the measuring tube, the pressure is read, and the decrease is noted. In the case of cuprous chloride it is more convenient to work with a solution in ammonia than with one in hydrochloric acid, and before taking the reading the gas must be washed with dilute sulphuric acid.

A suitable quantity of the residual gas is then mixed with oxygen or air, and after sparking in the explosion vessel, E, the contraction is noted, and any carbon dioxide formed is absorbed by means of potash.

After the completion of an analysis the whole apparatus should be washed out with sulphuric acid, in order to diminish the possibility of fouling by alkalies.

The Lunge Nitrometer.

In the nitrometer, nitric acid and nitrates may be estimated by measuring the volume of gas evolved on treatment with concentrated sulphuric acid in presence of mercury. Technically, the nitrometer is most frequently used in estimating the percentage of nitric acid in vitriol or in nitrating mixtures, so that snap samples of a nitrating mixture at various times may serve as a rapid method of estimating the course of a nitration.

The measuring tube C is filled with mercury by means of the levelling tube D, and a quantity of the acid under examination (the amount used being dependent upon the HNO_3 present) is run into A, and allowed to run into C. The cup A is washed with a further quantity of pure H_2SO_4, which is then run into C, so that the acid in C is approximately 80% H_2SO_4, taking care that no air bubbles pass into C. The tube C is then well shaken until no further gas is liberated, and the apparatus allowed to stand one hour. The mercury levels are adjusted so that the level in D is higher than that in C by an amount equal to 1/7th of the layer of H_2SO_4 present in C (to correct for gravity of H_2SO_4).
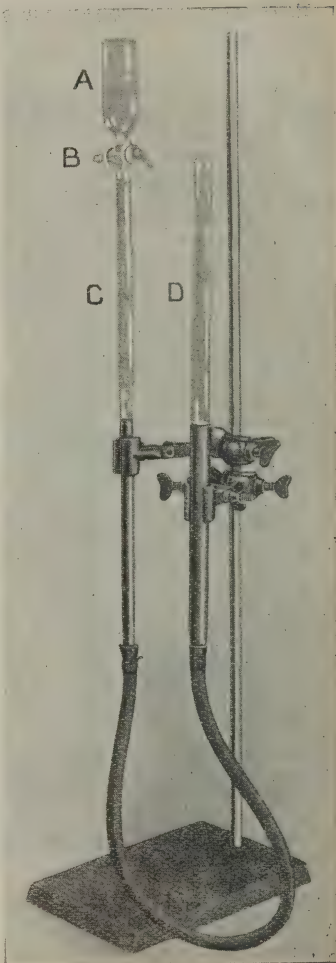
The volume of the gas, the temperature and pressure in the laboratory are taken, and then the gas volume is corrected to 0° and 760 mm., and from this the percentage of HNO_3 may be obtained.

The Du Pont Nitrometer.

The Du Pont nitrometer, as illustrated, is a more delicate and more convenient apparatus for the volumetric determination of nitric acid or nitrates, and is extensively used in the U.S.A. (see J. R. Pitman, *J.S.C.I.*, 1900, **19**, 982).

The main components are the generating bulb (E) and the mercury reservoir (F), which correspond to the two limbs of the Lunge nitrometer. The generating bulb is connected by means of a two-way tap to the cup or to the measuring chamber (D), which has a volume of 240·4cc., and is calibrated to read in percentages of nitrogen, being graduated in $^1/_{100}\%$ from 10 to 14%. The measuring burette (A) may be used in place of D in case a wider range of measurement is necessary. It is usually graduated to hold 3·001 milligrams of NO at 20°C. and 760 mm. pressure, and is divided into 100 units (sub-divided into tenths) When compensated, the gas from ten times the molecular weight in milligrams of a nitrite of formula RNO_3 (or five times the molecular weight of $R(NO_3)_2$) should exactly fill the burette. From this, the percentage of nitric acid in a mixed acid is given by the following formula :

$$\frac{63 \cdot 02\, r}{100\, w},$$

where r is burette reading, and w is weight of mixed acid in grams.
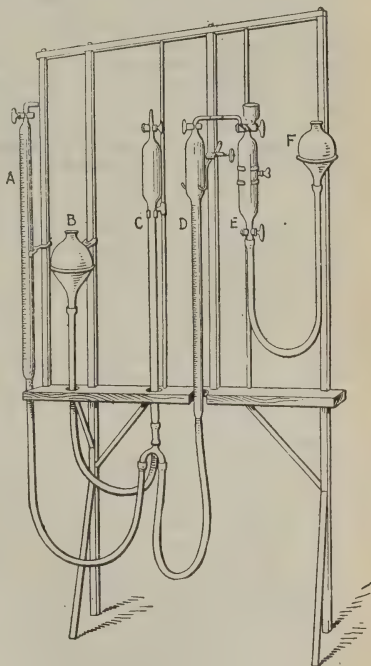
C is a compensating burette similar in form to the chamber D, and B is the levelling bulb and mercury reservoir for A, C, and D.

Standardisation of the apparatus.

The most convenient and rapid method of standardisation is as follows :—20–30 cc. of sulphuric acid are drawn into the generating bulb E through the cup, together with about 210 cc. of air. The taps are then closed, and the bulb thoroughly shaken to dry the air, which is then forced over into the compensating chamber C. Exactly 1 gram. of chemically pure potassium nitrate dissolved in 2 to 4 cc. of water is introduced into the generating chamber, and washed in with three or four amounts (total 20 cc.) of pure concentrated sulphuric acid. The mixture is shaken as below, and the generated gas run into the measuring burette A or D. The columns of mercury in the measuring burette and the compensating chamber are balanced, so that the gas in the measuring burette and the compensating chamber are balanced, so that the gas in the measuring burette reads 13·85 (= %N in KNO_3). The level of the mercury in C is marked, and the standardisation is completed. (For fuller details, see Scott, "Standard Methods of Chemical Analysis.")

Method of making the test.

Such an amount of the nitric acid, mixed acid, or nitrate (in this case, dissolved in 2 to 4 cc. of water) as will generate 172 to 240 cc. of gas is placed in the cup of the generating bulb, and then drawn into the bulb. The cup is rinsed out with three or four amounts (total 20 cc.) of pure concentrated sulphuric acid, each washing being run separately into the generating bulb. The lower tap is left open during this charging, and also while the bulb is shaken well until apparently all the gas is evolved. The shaking is repeated for two minutes with this tap closed, and then the reservoir is lowered until about 60 cc. of mercury remain in the generating bulb. (If too much mercury is left in the bulb, a long time will be required for the residue to settle, and some gas may be held in suspension by the mercury, leading to inaccurate results.) The generated gas is transferred to the reading burette D, and after cooling for a few minutes, both burettes are balanced, so that the mercury in the compensating burette is level with the standardising mark as well as with the column in the reading burette; the reading is then taken.

If exactly 1 gram. has been used, the reading will give percentage of nitrogen. For other amounts, the reading divided by weight used gives percentage of nitrogen, whilst percentage of nitrogen, multiplied by 4·5 gives percentage of nitric acid.

Whenever it is not practicable to produce between 172 and 240 cc. of gas, the measuring burette A should be used, together with the formula under description of the apparatus.

The procedure may be used to estimate nitrites as well as nitrates.

Ammonium Salts by the Hypobromite method.

Ammonium salts are decomposed by an alkaline solution of sodium hypobromite; for example :

$$2NH_4Cl + 2NaOH + 3NaOBr = 2NaCl + 3NaBr + 5H_2O + N_2.$$
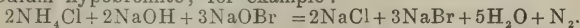
If the reaction takes place in a nitrometer, the nitrogen liberated may be measured.

Wt. of 1 cc. pure nitrogen at N.T.P. = 0·0012507 grm.

The hypobromite solution is prepared from 100 grm. of caustic soda solution (Sp. Gr. 1·1) and 4 grm. of bromine.

To correct for the solubility of nitrogen in the hypobromite solution, 2·5 per cent. of the volume of nitrogen found is to be added (Lunge).

Factors for Conversion of Volumes of Gas.

Substance	Method	Gas	1 cc (N.T.P.) = mgrm.
Organic compds.	Dumas	N_2	1·2507 N_2
Chile saltpetre	Nitrometer	NO	3·795 $NaNO^3$
Nitrosyl sulphuric acid	,,	NO	$\begin{cases} 1·697\ N_2O_3 \\ 2·813\ HNO_3 \\ 3·795\ NaNO_3 \end{cases}$
Nitroglycerin	,,	NO	3·379 $C_3H_5 (NO_3)_3$
Pyrolusite	By H_2O_2	O_2	3·880 MnO_2
Bleaching powder	,,	O_2	1·583 Cl_2
$KMnO_4$	,,	O_2	0·7143 O_2
Carbonates	Decomp. HCl.	CO_2	4·468 $CaCO_3$

ULTIMATE ORGANIC ANALYSIS.

Carbon and Hydrogen.

When it is necessary to find the quantitative ultimate composition of an organic substance, the analysis is made by means of a combustion.

A known weight of the substance is burnt in a tube containing copper oxide, the water and carbon dioxide evolved being collected; from the weight of these products the hydrogen and carbon in the substance may be calculated. The oxygen is generally determined by difference, as no satisfactory method for the estimation of oxygen in organic compounds is available.
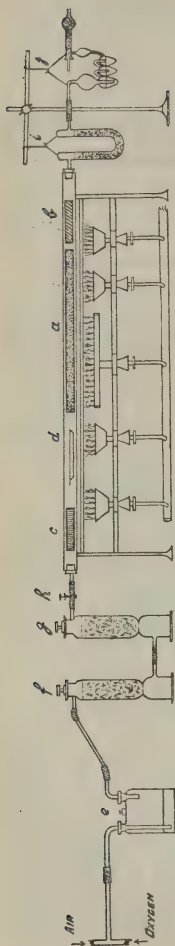
The apparatus employed is shown in the accompanying diagram, the combustion taking place in a hard glass tube (about 30 inches long), which is heated by means of a special combustion furnace. The space a contains granulated copper oxide; b is a spiral of copper gauze employed to decompose any oxides of nitrogen formed by combustion; if the substance is known to be free from nitrogen, this may be omitted. The front end of the tube is empty to allow the insertion of the boat d. Next to the boat is placed a spiral of copper gauze, previously oxidised by heating to redness in the presence of air or oxygen, in order to prevent the volatile and gaseous products from diffusing backwards along the tube. Arrangements are made to allow the passage of both air and oxygen through the tube, both being previously passed through the same purifying devices e, f, and g. e is a wash-bottle containing concentrated sulphuric acid to remove dust and water; f and g are towers filled with sticks of caustic potash. Between g and the tube is a screw clip h to allow regulation of the rate of flow of the oxygen or air. At the far end of the combustion tube are connected a calcium chloride tube (i) for the absorption of water and potash bulbs (j) for the retention of carbon dioxide. In case no calcium chloride tube is attached with calcium chloride or soda lime it is necessary to employ a further U-tube packed with calcium chloride or soda lime to collect any moisture which the gases may have absorbed from the potash solution (40% KOH). This latter vessel is always weighed together with the bulbs. Previous to making an estimation, the apparatus should be carefully examined to ensure that all joints are completely gas-tight. The air and oxygen required may be contained in gas-holders.

The method of procedure is as follows: The tube is first heated for a period of one hour to remove completely dust and moisture, after which the front end is allowed to cool and the boat removed. 0·15 to 0·25 grm. of substance is weighed into the boat, and then the calcium chloride tube and potash bulbs are weighed and connected.*

The boat is now inserted in the tube and the diffusion spiral c returned. A current of air (about one bubble per second) is passed through the tube and the diffusion coil heated. When the coil c has attained a dull red heat, the boat is slowly heated. After the entire tube has become hot the air supply may be replaced by oxygen for a period of about one hour to ensure the complete combustion of all carbonised residue, after which the air supply is again connected, until the whole of the apparatus is filled with air. The calcium chloride tube and potash bulbs may now be disconnected and allowed to cool previous to weighing. The increase in weights of the calcium chloride tube and the potash bulbs show the yield of water and carbon dioxide respectively.

By multiplying the water yield by 2/18 (H_2/H_2O) the hydrogen content of the substance is obtained. Similarly the carbon content is calculated by multiplying the carbon dioxide yield by 12/44 (C/CO_2). The entire analysis requires a period of about four hours.

With substances containing sulphur the tube should be filled with lead chromate instead of copper oxide in order to retain the sulphur dioxide which is formed.

Halogens, Sulphur and Phosphorus.

Halogens may be estimated by the Carius method, which consists of heating the substance with a small quantity of concentrated nitric acid in the presence of silver nitrate. By this means the carbon and hydrogen are oxidised and the halogens form insoluble silver salts which can be estimated gravimetrically. The estimation is carried out in a sealed glass combustion tube, which is heated in a tube furnace provided

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* If nitrogen or halogens are present in the substance, it will be necessary to reduce the copper spiral b by heating to redness and immersing in methyl alcohol vapour in a test-tube, removing the methyl alcohol by heating the spiral to about 200°C.

with wrought-iron pipes, inside which the heating may take place, thus minimising any danger from bursting.

Sulphur may be estimated either by fusion and precipitation (as $BaSO_4$), or by oxidation with concentrated nitric acid by the Carius method (omitting the silver nitrate) and precipitation. Phosphorus may be oxidised by the Carius method, after which the estimation may be completed in the usual way.

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Volumetric Determination of Nitrogen. (Dumas).

A combustion tube 70 cm. long is filled in the following order : at the sealed end of the tube is placed a layer of 10 cm. of fragments of magnesite, held in position by a loose plug of asbestos, then a layer of 10 cm. of granular copper oxide, followed by 0·3–0·6 grm. of the substance and powdered copper oxide, then a layer of 40 cm. of granular copper oxide, and finally a roll 10 cm. long of copper gauze.

The end half of the magnesite is heated to replace the air in the tube by carbon dioxide. When this process is complete the gas evolved is completely soluble in caustic potash solution. This solution is contained over mercury in a volumenometer, provided with a levelling tube. The combustion is then made as usual, and the nitrogen evolved collected over the caustic potash solution. The remainder of the nitrogen is driven into the volumenometer by heating the remainder of the magnesite. After levelling, the temperature and volume of the gas and the barometric pressure are noted.

$$\% \text{ N} = \frac{V (b-f)}{760 (1 + 1/273\,t)} \times \frac{28\cdot02}{22403} \times \frac{100}{W} = K \times \frac{V (b-f)}{W}$$

where V = Volume of nitrogen in cc. at $t°$C. and barometric pressure b mm.

f = Vapour pressure of the caustic potash (Sp. Gr. 1·29) used at $t°$C. (See Physico-Chemical Constants.)

and W = Weight of substance used.

Table giving Values of $K\left(= \dfrac{100}{760(1 + \tfrac{1}{273}\,t)} \times \dfrac{28 \cdot 02}{22403}\right)$

°C.	K	°C.	K	°C.	K
0	0.00016457	11	0.00015819	22	0.00015230
1	16397	12	15764	23	15178
2	16337	13	15709	24	15127
3	16278	14	15654	25	15076
4	16219	15	15600	26	15026
5	16161	16	15546	27	14976
6	16103	17	15492	28	14926
7	16045	18	15439	29	14877
8	15988	19	15386	30	14828
9	15931	20	15334	31	14779
10	15875	21	15282	32	14730

Determination of Nitrogen. (Kjeldahl).

Kjeldahl method.

0·2—2·0 grm. of the substance (such a quantity should be taken that the nitrogen content is equivalent to about 40 cc. of the standard acid), together with 0·7 grm. of mercuric oxide, or its equivalent in metallic mercury, and 20—30 cc. of concentrated sulphuric acid, are weighed into a long-necked resistance (Kjeldahl) flask. The flask and contents are then heated for a time below the boiling-point of the acid, until all frothing has ceased. Excessive frothing may be overcome by the addition of a small piece of paraffin wax. The heating is increased until the acid boils, and boiling continued until the acid is colourless, or almost colourless, so that further heating causes no more decrease in colour.

After cooling, the acid is diluted with approximately 200 cc. of water, and to this are added a few pieces of granulated zinc or pumice stone, if necessary to prevent bumping, and 100 cc. of potassium sulphide solution (40 grm. commercial potassium sulphide per litre). Approximately 100 cc. of 30% sodium hydroxide solution (sufficient to make the mixture strongly alkaline) are poured carefully down the side of the flask, so as to avoid immediate mixing, and the flask connected to the distillation apparatus, which consists of the distillation flask, bulb-trap to prevent the sodium hydroxide being carried

over mechanically, condenser, and an adaptor, of which the lower end dips under the surface of the liquid in the receiving flask. This consists of a measured quantity of standard acid (say 50 cc.). The distillation flask is shaken to mix the contents thoroughly, and approximately 150 cc. distilled over into the standard acid, excess of which is titrated by means of standard alkali, using cochineal or methyl red as indicator.

0·1—0·3 grm. of copper sulphate crystals may be used in addition to, or in place of, the mercury; in such case, the final colour after boiling would be pale-green. In case mercury or mercuric acid is not used, the use of potassium sulphide is unnecessary.

Particular care should be taken that all reagents are free from nitrogen compounds, and they should be tested by means of a blank experiment on pure cane sugar.

N/2 acid and alkali are generally used, but in determining small amounts of nitrogen, N/10 acid and alkali should be used. The strength of the standard acid should be determined gravimetrically; sulphuric as barum sulphate, hydrochloric as silver chloride; and the alkali standardized against this.

The Kjeldahl method is not available for nitro-, nitroso-, azo- or diazo-compounds, or for hydrazines, nitrates or nitrites, without further modification.

Kjeldahl-Gunning method.

0·2—2·0 grm. of the substance, together with 10 grm. of powdered potassium sulphate or 10 grm. of anhydrous sodium sulphate, and approximately 20 cc. of concentrated sulphuric acid, are treated exactly as in the Kjeldahl process, except that after dilution, no potassium sulphide is added. 0·1—0·3 grm. of copper sulphate crystals may be added to the mixture.

Kjeldahl-Gunning-Arnold method.

0·2—2·0 grm. of the substance, together with 15—18 grm. of potassium sulphate (or anhydrous sodium sulphate), 1 grm. of copper sulphate, 1 grm. of mercuric oxide, or its equivalent in metallic mercury, and 25 cc. of concentrated sulphuric acid, are heated gently in a Kjeldahl flask until frothing subsides, and then boiled until the mixture is colourless or practically so. The mixture is cooled, diluted with 200 cc. of water, 50 cc. of potassium sulphide added, made strongly alkaline with sodium hydroxide solution, and distilled as in the original Kjeldahl method.

Kjeldahl Method modified to include the Nitrogen of Nitrates.

0·2—2·0 grm. of the substance is placed in a Kjeldahl flask, and to this are added—

(*a*) 30 cc. of concentrated sulphuric acid containing 1 grm. of salicylic acid, the whole shaken, allowed to stand for 30 minutes, 5 grm. of sodium thiosulphate crystals added, and digested as below; or

(*b*) 30 cc. of concentrated sulphuric acid containing 2 grm. of salicylic acid, allowed to stand 30 minutes, and then grm. zinc dust added gradually with shaking, and digested as follows :—

The mixture is heated gently until all danger from frothing over has passed, and then boiled until white fumes no longer escape from the flask, which takes about 5—10 minutes. Approximately 0·7 grm. of mercuric oxide is added, or its equivalent in mercury, and then the boiling is continued until the acid is practically colourless. 10 cc. of acid should be added to prevent the material becoming solid in the flask, and the determination completed as in the original Kjeldahl method.

The above methods are substantially the Official Methods of the Association of Official Agricultural Chemists of the U.S.A.

ELECTRO-CHEMICAL ANALYSIS.

Sources of Electrical Energy, etc.

The sources available for electro-deposition are accumulators, Gülcher thermopiles, Bunsen cells, etc., but the first-named are invariably used for electrochemical analysis.

In order to obtain a satisfactory deposit, it is necessary to work at a suitable current density,

C.D. = amperes per square decimetre

The current is adjusted by means of a rheostat.

$$C = \frac{E - e}{R}$$

where C = Current in amperes,

E = Main voltage,

e = Back E.M.F. in volts,

R = Resistance in ohms.

Apparatus.

A platinum dish may be employed as cathode, but this is much more expensive than the equally service-able gauze cylinder or flag electrode.

The anode may be a cylinder, or, preferably, a piece of thick platinum wire coiled concentrically, the current being conducted by a portion of the wire bent vertically to the circle.

Platinum basins must not be heated direct, but should be heated on a water-bath.

For antimony, bismuth, mercury, and lead dioxide and manganese dioxide, a roughened gauze cathode is most satisfactory, but should not be finer than 70–80 meshes per sq. cm.

More rapid working is effected by the use of rotating electrodes. A suitable cathode for this purpose, for which a higher C.D. may be used, is a small sand-blasted cylinder of platinum gauze. It is more satisfactory to have a stationary cathode in the form of a platinum gauge cylinder, and to rotate rapidly the anode, which may be a spiral of iridio-platinum.

To prevent loss of liquid by spurting, due to liberation of gas, the containing vessel is covered with a watch-glass, pierced by a hole through which passes the thick vertical platinum wire which carries current to the anode.
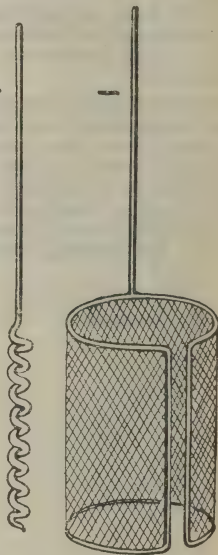
The electrolysis is continued until a drop of the liquid on testing is found to be free from the metal which is being deposited. The current is discontinued when any liquid which would dissolve the deposit has been replaced by a syphoning arrangement. The cathode is then washed with water, alcohol, and ether, and then dried for a short time at 100°C., a higher temperature being necessary in the case of dioxide deposits.

In the following, several methods are outlined which have been suggested for electrochemical analyses and separations :

Antimony.

The precipitated antimony sulphide is dissolved in 80 cc. of saturated sodium sulphide solution (Na_2S). At ordinary temperature : C.D. = 0·3 ampere ; E.M.F. 1·5 volts.

At 50°C. : C.D. = 1 ampere ; E.M.F. = 2 volts.

The addition of 1 grm. potassium cyanide is an advantage, as it prevents formation of polysulphides.

Cadmium.

(1) A moderate excess of potassium cyanide is added to a solution containing 0·5 grm. of cadmium, preferably as sulphate or acetate.

C.D. = 0·6 ampere ; E.M.F. = 4·6 volts at ordinary temperature.

C.D. = 0·2 ampere ; E.M.F. = 4   volts at 50°C.

(2) 3 grm. of ammonium sulphate, acetate or formate are added to the cadmium solution, and then 1 cc. of a 20 per cent. solution of the corresponding free acid.

C.D. = 0·2 ampere ; E.M.F. = 2·5 volts at 60°C.

Copper.

(1) In absence of chlorides, bismuth, arsenic, antimony, tartaric and citric acids. To the solution of nitrate or sulphate, 5 per cent. of concentrated nitric acid is added.

C.D. = 1 ampere ($\frac{1}{2}$ ampere if other metal present) ; E.M.F. = 2·5 volts. It is preferable to warm the solution to 50°C. and to use stirring apparatus. The final solution is gradually syphoned off and replaced by water before breaking the current. When most of the copper has been deposited, about 0·5 grm. urea should be added to decompose any nitrite which may have been formed as this prevents complete deposition of copper.

(2) Potassium cyanide is added in slight excess until the yellow ppt. first produced has dissolved.

C.D. = 1 ampere ; E.M.F. = 5–6 volts (4–5 volts in warm solutions). About two hours are required for complete deposition.

Gold.

(1) If strongly acid the gold solution is almost neutralised with caustic potash. 2 grm. of pure potassium cyanide added to convert into the auricyanide.

At ordinary temperature : C.D. = 0·25 ampere ; E.M.F. = 3 volts.

At 50°C. : C.D. = 0·7 ampere ; E.M.F. = 3 volts.

(2) 30 cc. of saturated sodium sulphide solution are added, and the solution electrolysed at the ordinary temperature.

C.D. = 0·2 ampere ; E.M.F. = 2 volts.

(3) 6 grm. of ammonium thiocyanate are dissolved in 60 cc. water, the solution warmed to 50°C., and the gold solution added with constant stirring.

At ordinary temperature or 50°C. : C.D. = 0·3 ampere ; E.M.F. = 1·5 volts.

Iron.

The ferrous or ferric chloride or sulphate solution containing about 1 grm. of iron is almost neutralised with ammonia and poured into a concentrated solution of 6 grm. of crystallised ammonium oxalate, 5 cc. of a saturated solution of borax added, and the solution warmed.

C.D. = 0·6–1 ampere ; E.M.F = 3·5 volts.

Lead.

A sand-blasted platinum dish or, preferably, gauze flag anode, roughened by a sand-blast, is used. The nitrate solution, containing 1 grm. of lead, should be free from silver and chlorine compounds. 20 per cent. of concentrated nitric acid is added.

C.D. = 0·5 ampere ; E.M.F. = 2 volts at ordinary temperature. In case metallic lead separates at the cathode, more nitric acid is added.

The deposit of lead dioxide is dried at 200°C.

Manganese.

A roughened anode must be used. To the manganese sulphate solution (containing 0·15 grm. manganese) are added 10 grm. ammonium acetate and 2 grm. of chrome alum (Engels, *Zeitschr. f. Elektrochem.*, **2**, 413), and the solution warmed to 75°C.

C.D. = 0·6 to 0·9 amperes ; E.M.F. = 3·5 volts.

The deposit is washed, dried, and ignited to Mn_3O_4, which is then washed and reignited.

Mercury.

(1) 2 per cent. of nitric acid is added (5 per cent. in

presence of other metals), and the solution warmed to 50°C.
    C.D. = 1 ampere (0·5 ampere in presence of other metals);
E.M.F. = 4·0 volts. The cathode should be roughened.
    (2) 1 per cent. of hydrochloric or sulphuric acid is added.
    C.D. = 0·5-0·8 amperes (raised to 1 ampere towards end);
E.M.F. = 3·5 volts.
    The deposit must be dried in a dessicator, as alcohol loosens
the globules.

Nickel or Cobalt.

The nickel sulphate solution (free from nitric acid) is added
to a mixture of a concentrated solution of 5 grm. of ammonium
sulphate and 30-40 cc. of concentrated ammonia solution (for
1 grm. nickel). The solution is stirred, but the deposition is
carried out in the cold with C.D. = 1 ampere.
    The process for cobalt is identical.

Silver.

3-4 grm. of pure potassium cyanide are added to the solution
containing 0·5 grm. of silver.
    C.D. = 0·3 ampere; E.M.F. 3·5 volts at ordinary temperature.
    C.D. = 0·6 ampere; E.M.F. 5·6 volts at 50°C.

Tin.

If present in sodium sulphide solution, 20 grm. of pure
ammonium sulphate are added, and the solution warmed until
no more hydrogen sulphide is evolved, and then boiled for
several minutes.
    An excess of yellow ammonium sulphide is added to a
solution containing 0·4 grm. tin, and the solution warmed
to 50°C.
    C.D. = 1 ampere (gradually reduced to 0·3 ampere);
E.M.F. = 3·5 volts.
    The electrolysis is continued until addition of an excess of
hydrochloric acid gives a precipitate of pure sulphur.

Zinc.

Electrodes of nickel, or platinum coated with copper, are used.
4 grm. of potassium oxalate and 3 grm. of potassium sulphate
are added to the neutral zinc sulphate or nitrate solution
(0·3 grm. of zinc). The deposition is carried out with stirring
in the cold.
    C.D. = 0·5 ampere; E.M.F. = 4 volts.
    After a short time, a few cc. of a 5 per cent. oxalic acid
solution are added.

Electrolytic Separations.

Separation of Antimony and Tin.

The mixture of sulphides (0·5 grm. metal) is dissolved in 80 cc. of a saturated solution of sodium sulphide, 2 grm. of caustic soda added, and the solution warmed to 60°C. The antimony is deposited; C.D. = 0·5 ampere

After the antimony has been removed, the solution is boiled for 15 minutes with 25 grm. of ammonium sulphate. After cooling to 60°C., the solution is electrolysed; C.D. = 1·0 ampere.

Separation of Copper and Iron.

2 per cent. of sulphuric acid is added to a solution of the sulphates, and the warm solution electrolysed with C.D. = 1 ampere. After all the copper has been deposited, the cathode is removed and replaced by a fresh electrode. A solution containing 4 grm. of ammonium oxalate is added, the solution neutralised by suitable additions of ammonia or oxalic acid, heated to 50°C., and electrolysed with C.D. = 1 ampere.

Separation of Copper and Lead.

The anode used is a roughened flag electrode, a wire (bent as usual for an anode) being employed as cathode. 10 per cent. of concentrated nitric acid is added, and the solution warmed to 60°C.

C.D. = 1·5 amperes; E.M.F. = 1·5 volts.

The anode (on which lead dioxide has been deposited) is replaced by a fresh electrode to act as cathode in the electro deposition of the copper, the current being reversed.

Separation of Copper and Silver.

The method used depends upon the variation of the E.M.F. in nitric acid or cyanide solution.

(1) In nitric acid solution, the silver is deposited first at below 1·3 volts.

(2) In cyanide solution, an excess of 4 grm. of potassium cyanide is used, and the silver is deposited first at below 1·6 volts. Before depositing the copper, sulphuric acid is added *in the fume cupboard* to decompose part of the potassium cyanide.

Separation of Copper and Zinc.

The copper is deposited from nitric acid solution, and the solution remaining evaporated with sulphuric acid before depositing the zinc in oxalic acid solution.

Separation of Lead and Silver.

10 cc. of concentrated nitric acid are added, the solution heated to 80°C., and electrolysed, using C.D. = 0·15 ampere. Silver is deposited on the cathode and lead dioxide on the anode.

Removal of deposits.

Antimony, by a mixture of nitric and tartaric acids.

Cobalt, by warming with concentrated nitric acid.

Gold, by warming with potassium cyanide solution to which has been added several cc. of hydrogen peroxide.

Iron, by warming with dilute sulphuric acid.

Lead dioxide, by warming with a mixture of glucose and nitric acid (1 : 1), or by adding dilute nitric acid and placing a piece of zinc or copper foil in contact with the electrode to form a galvanic couple.

Manganese oxide (Mn_3O_4), by warming with concentrated hydrochloric acid.

Mercury, by heating in a Bunsen flame.

Nickel, by warming with nitric or sulphuric acid, taking great care that all the deposit has been dissolved before heating the platinum electrode, as nickel tends to become ' passive."

Silver, by potassium cyanide solution.

Tin, by boiling with concentrated hydrochloric acid, or by covering with dilute sulphuric acid and making anode with copper wire as cathode.

Zinc, by warming with a strong solution of caustic soda.

SPECTRUM ANALYSIS.

Flame Spectra.

Care must be taken to adjust the spectroscope so that the flame visible is above the blue cone; otherwise the green and blue bands of the carbon spectrum of the flame may interfere. The more characteristic lines in each spectrum are denoted by Greek letters. (See Diagram on next page.)

The wave-lengths (λ) are given in $\mu\mu$.

Taking $Na = 50$ on the scale of the spectrometer:

Kα is at scale division			17
Liα	,,	,,	32
Tl	,,	,,	68
Srδ	,,	,,	106
Inα	,,	,,	111
Inβ	,,	,,	149
Kβ	,,	,,	154
H	,,	,,	162

Sodium. Golden-yellow line at $\lambda589.3$ (D line); with fairly powerful spectroscope double line at $\lambda589.6$ and $\lambda589.0$.

Potassium. Red double line (α) at $\lambda769.9$ and $\lambda766.5$; violet line (β) at $\lambda404.4$.

Lithium. Red line (α) at $\lambda670.8$; faint golden-yellow line (β) at $\lambda610.3$.

Rubidium. Violet double line (α and β) at $\lambda420.2$ and $\lambda421.5$; red double line (γ and δ) at $\lambda781.1$ and $\lambda795.0$.

Cæsium. Blue double line (α and β) at $\lambda455.5$ and $\lambda459.3$.

(Rubidium and cæsium must be separated from large amounts of potassium and sodium salts, by fractional crystallisation of the acid oxalates, etc.)

Calcium. Golden-yellow band (α) at $\lambda620.3$ to $\lambda618.2$; yellowish-green band (β) at $\lambda554.4$.

Strontium. Red or golden-yellow bands are produced at $\lambda686.3$, $\lambda674.4$ (β), $\lambda662.8$ (γ), $\lambda649.9$, $\lambda646.5$, $\lambda635.1$, $\lambda606.0$ (α); blue line (δ) at $\lambda460.7$.

Barium. Green line (α) at $\lambda553.5$; green bands at $\lambda534.7$ (γ), 524.3 (δ), 513.7 (β), 500.0; blue band at 487.4.

Calcium, strontium, and barium in admixture. Only the following are characteristic:

Calcium: golden-yellow band (α).

Strontium: golden-yellow band (α); blue line (δ).
Barium: green bands (β, γ, and δ).

Thallium. Green line at λ535·0.

Indium. Blue line at λ451·1; violet line at λ410·1.

Copper. Green lines at λ550·7 and λ538·6; blue bands at λ443·7 to λ441·3 and λ435·4 to λ433·2; continuous spectrum in yellow and green.

Manganese. Two golden-yellow bands; four green bands of which λ559·2, λ539·2 and λ515·8 are characteristic.

Boric acid. Four golden-yellow and yellow bands; two green bands; two blue bands. Yellow band at λ548·1 to λ544·0 and green bands at λ519·3 and λ491·2 are characteristic.

Spark Spectra.

Only the wave lengths of the stronger lines are mentioned.

Iron. Green lines at 537·0, 532·6, 526·6, 523·2, 519·2, 516·8, 513·9, 495·9, 492·3; blue lines at 489·1, 487·4.

Nickel. Green lines at 547·7, 508·1; blue line at 471·5.

Cobalt. Green lines at 535·3, 534·0, 528·0, 526·7.

Chromium. Green line at 520·7; blue lines at 429·0, 427·5, 425·4.

Manganese. Golden-yellow line at 601·7; blue lines at 482·4, 478·4, 476·6, 475·4.

Zinc. Golden-yellow line at 536·6; blue lines at 481·0, 472·2, 468·0.

Cadmium. Red line at 643·9; green line at 508·6; blue lines at 480·0 and 467·8.

Magnesium. Green line at 518·3.

Antimony. Golden-yellow line at 600·5; green line at 556·8

Bismuth. Green line at 555·2; blue line at 472·4.

Lead. Green line at 500·5; violet line at 405·8.

Mercury. Green line at 546·1; blue line at 435·8.

Tin. Yellowish-green line at 563·2; blue line at 452·5.

Copper. Green lines at 521·8, 515·3.

Silver. Green line at 546·5.

Gold. Golden-yellow line at 627·8; yellow line at 583·7.

Platinum. Green lines at 547·6, 530·2

Palladium. Green lines at 529·6, 511·7.

Ca

Sr

Ba

Hg

In

Tl

β ε α δ γ β γ α δ α γ δ β ε β α

800 750 700 650 600 550 500 450 400

150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
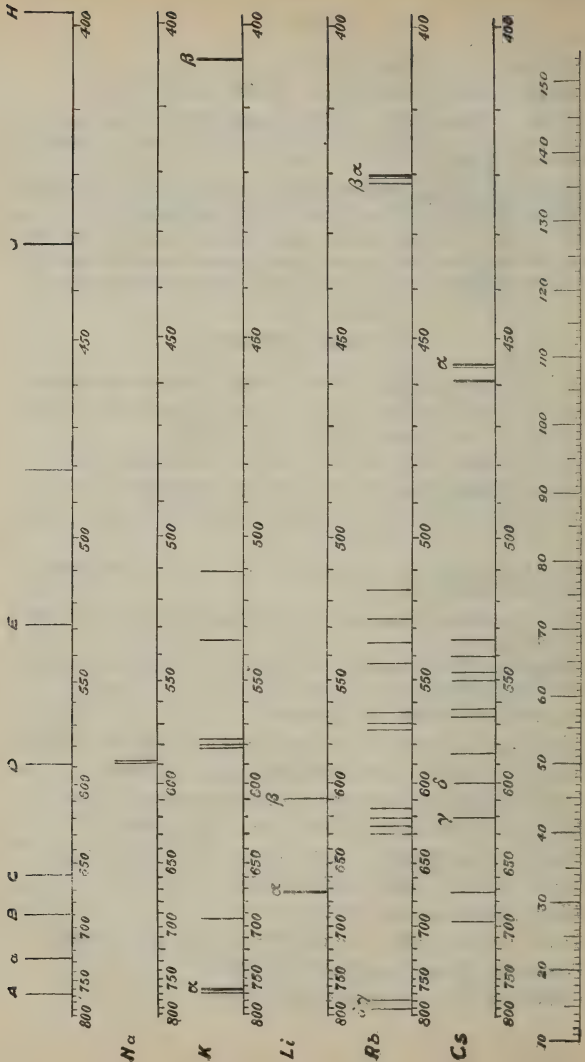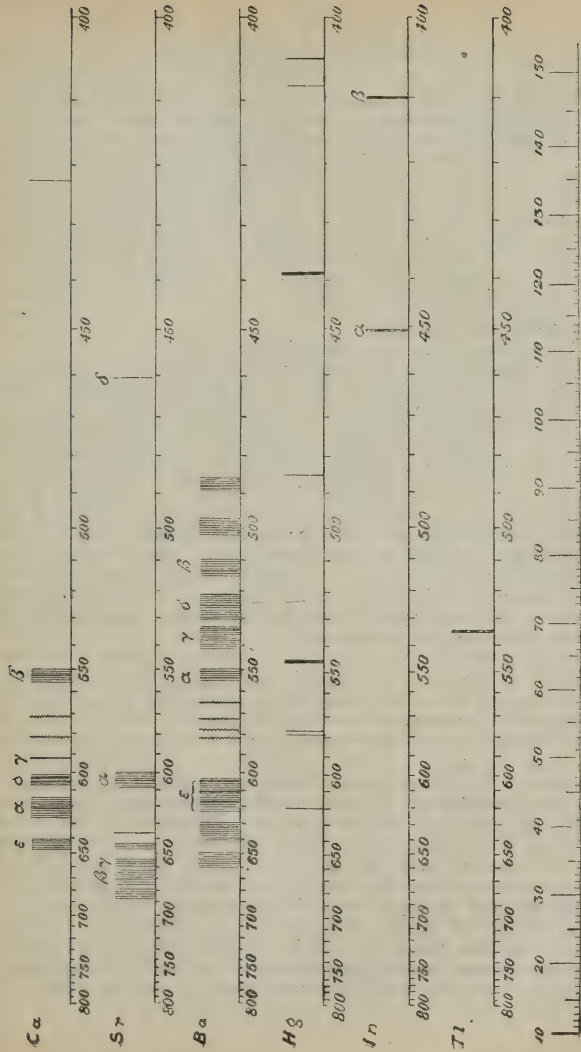
. WATER ANALYSIS.

S. E. MELLING, F.I.C.

For the complete diagnosis of the quality of water intended for domestic consumption, careful attention should be given to all available geological and metereological data as well as to the chemical analysis, physical characteristics, microscopical features and bacteriological examination. In the absence of any geological and metereological data, it may be impossible to account for the apparent anomalies which the various bio-chemical and other results indicate; hence the necessity for such local information as nature of strata and general catchment area, method of storage, proximity to human habitation, rainfall, etc.

Sampling and delivery.

Correct sampling is of vital importance.

For chemical analysis, clean transparent $2\frac{1}{2}$ litre bottles are convenient, the stoppers and necks being protected from dirt by some suitable form of capping. If drawn from tap or pump, the water should be allowed to run freely for several minutes (except, of course, in cases of plumbo-solvency determination) prior to the quiet filling of the bottle up to within, say, half an inch of the stopper. In sampling from a reservoir or stream, surface water should be excluded by holding the bottle one foot below the surface, and as far away from the bank as practicable, taking due precautions to avoid disturbing sediment. The interval between collection and examination is of great importance, and the shorter the interval, the more reliable will be the results, especially with reference to the organic data.

For bacteriological examination, the sampling must be carried out under strictly aseptic conditions, but it will rarely be necessary to collect more than about 200 cc. in a well-cleaned and previously sterilised stoppered bottle. If drawn from service mains, the water should be allowed to run for at least 15 minutes before sampling. In sampling from streams, it is of importance to remember that even flowing water deposits bacteria on the side of the stream bed; hence the sediment must on no account be disturbed. The most serviceable and simplest sampling apparatus is a modification of the Pasteur bulb in the form of a thick glass tube drawn out at one end to about 1/30 in. diameter. A small amount of pure water is introduced, boiled, and the tube sealed off whilst full of steam. When the tube is submerged, the drawn-out end is snapped with sterile forceps, and the broken end is then re-sealed. Suitable sterile metal containers are desirable for transport; it is preferable to

pack in an ice-box, but any device will serve which maintains the sample at or about 4°C. A simple apparatus such as the above may be used (duly weighted), with the aid of a fishing rod, for collecting samples from reservoirs, by attaching a stout thread to the sealed end of the tube and breaking at the right moment by a sharp pull.

Physical Characteristics.

Appearance. Observation in a two-foot glass column is now replaced by more exact methods for turbidity determination (against pure silica suspensions, etc.), and for tintometric measurements, either by the Lovibond instrument or platinum-cobalt comparates. (For details of the latter see American Public Health Association, *Standard Methods of Water Analysis*, p. 9.)

Odour. An observation should be taken at the laboratory temperature after shaking the bottle vigorously when about two-thirds full. In addition about 200 cc. should be transferred to a clean capacious flask fitted with a pressure release, heated to about 50°C., and the odour observed.

Taste. Occasionally, this observation is desirable, but useful information is only rarely gained.

Chemical analysis.

The data required may include : total dissolved solids, suspended matter, nitrogen in organic and mineralised combinations, oxygen absorbed from acid permanganate, combined chlorine, hardness, and metallic contamination. Results should be expressed in parts per 100,000.

Before commencing the organic analysis, which must always take precedence over other analyses, a portion of the well-shaken sample should be transferred to a clean cylindrical separator, and set aside overnight to settle (see microscopical examination); the settled solution is drawn off for the combined chlorine and other estimations of inorganic matter in solution.

Ammoniacal nitrogen (free and saline ammonia). The still and condenser are freed from ammonia by distilling 400 to 500 cc. of pure water to about half its volume, and then collecting a further 50 cc., which should give a blank test on standing five minutes with Nessler solution ; the remaining contents of the flask are rejected. 500 cc. of the freshly-shaken original sample are introduced into the flask together with 5 cc. of a 10% solution of ammonia-free sodium carbonate. (At either this stage or when the temperature is raised, a useful indication of the approximate amount of iron, lime and magnesia salts present is frequently afforded by the volume of precipitate ; this may assist in determining the

amount of water to be subsequently taken for total saline matter and hardness estimations.) The distillation is carried out so that four 50 cc. quantities distil over in about 40 mins. Alternatively, 50 cc. is distilled off and Nesslerised; a further 150 cc. is collected in a cylinder, the ammonia content of which is determined by Nesslerising 50 cc. and calculating accordingly. Comparison is made with a series of suitable standards prepared by diluting standard ammonium chloride solution to 50 cc. in Nessler glasses with ammonia-free distilled water. (The latter is obtained, as required, by the distillation of tap-water to which has been added a slight excess of sulphuric acid.) Not more than 1 cc. of Nessler reagent [2] is necessary; the contents are mixed by pouring to and from a similar clean tube and are allowed to stand 5 mins. before comparison is made in specially clear tubes of identical internal diameter and make.

Albuminoid nitrogen. The contents of the distillation flask remaining after distillation of the ammoniacal nitrogen are allowed to cool somewhat, and 50 cc. of alkaline potassium permanganate [3] is added; four 50 cc. quantities are distilled off and ammonia estimated as above. A note is made of the rate of evolution of the ammonia.

Organic nitrogen. In routine sanitary analysis, this determination is rarely required. If essential, 500 cc. of the sample is evaporated to 100 cc., made alkaline with 10 cc. of 20 per cent. caustic soda solution, and a strip of aluminium foil introduced, when the reduction of nitrites and nitrates is completed in the course of 2 to 3 hrs.; the free ammonia is distilled off, and a Kjeldahl determination carried out on the residue.

Nitrous nitrogen (nitrites). Of the colorimetric methods available, probably that of Griess-Ilosvay is the most satisfactory. To 50 cc. of the sample (or, if necessary, 25 cc. made up to 50 cc. by the addition of nitrite-free distilled water) there is added 1 cc. each of sulphanilic acid [4] and α-naphthylamine acetate;[5] after mixing thoroughly, the sample is compared with a range of suitable dilutions of standard sodium nitrite.[6] Ten minutes should be allowed for the full development of colour before final comparison.

Nitric nitrogen (nitrates). The phenoldisulphonic acid method, being specific, is recommended, but the procedure has to be varied according to the degree of turbidity, the presence of colour and the amount of combined chlorine. The two former factors can generally be ignored; in exceptional cases, clarification with pure alumina cream (freshly ppd. aluminium hydroxide washed free from alkali) will be found necessary. The presence of combined chlorine not exceeding 2 parts per

100,000 is without influence; otherwise it must be removed by first neutralising 50 cc. of the sample with pure N/50 sulphuric acid, followed by the addition of sufficient, but not excess of, pure silver sulphate solution; the liquid is then made up to 100 cc. with distilled water, shaken, and 50 cc. filtered for the estimation. The determination is made by carefully evaporating to dryness in a glass dish; towards the end of the evaporation, the mass is allowed to cool, and is spotted with 1 cc. of the phenoldisulphonic acid,[7] and thoroughly triturated with a glass rod. If the residue is at all vitreous, the dish is warmed on the water-bath for a brief period. The mass is treated with 25 cc. of distilled water, and the solution transferred to a 100 cc. graduated flask, rinsing with a small amount of water; excess of ammonia is added, and the liquid made up to the mark. The intensity of the yellow colour imparted by the ammonium compound is proportional to the amount present; comparison should be made in 50 cc. Nessler tubes with varying amounts of a standard solution containing potassium nitrate similarly treated,[8] diluted to the mark with distilled water after the addition of ammonia.

Oxygen absorption test (reducing power). 250 cc. of the sample in a stoppered bottle (less, if the water is seriously polluted) is acidified with 10 cc. of sulphuric acid,[9] 10 cc. N/80 solution of potassium permanganate [10] added, and the mixture allowed to stand for 3 hrs. at 18°C., giving the contents an occasional shake. A "control" test is made simultaneously under precisely the same conditions, using 250 cc. of recently-boiled and cooled distilled water. An excess 10% potassium iodide solution is now added to sample and control tests, and the liberated iodine determined by titration with sodium thiosulphate (1 grm. per litre), using starch solution as indicator. The amount of oxygen absorbed by the sample is calculated from the difference in the titrations.

A correction is necessary in case nitrites, ferrous iron, etc., are present.

Total solids (including suspended matter). A suitable quantity (100 cc. to 500 cc.) of the well-shaken sample is evaporated in a platinum dish on a water-bath. The residue is dried in the oven at 105°C. for an hour.

Non-volatile solids. The above residue is cautiously ignited, the temperature being gradually increased to a dull red heat. Observations on ignition frequently give valuable information; for example, degree of charring and odour (whether vegetable or nitrogenous organic matter), evolution of oxides of nitrogen, etc.

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Suspended matter. In the majority of cases, water submitted for sanitary analysis contains only traces of suspended matter, and, unless a large volume of the sample is available, direct estimation is inexpedient. For this reason, it is doubtful whether much reliance can be placed upon the difference figure between the estimation of total solids of the shaken and filtered samples. Alternatively, in cases in which it is obvious that suspended matter is present in appreciable extent, say $\frac{1}{2}$ grain per gallon or upwards, an estimation can be made of the deposit, after careful washing and centrifugalising, following its microscopical examination.

Hardness. The determination of the soap-destroying power of a water is generally effected by titration with standard soap solution, and is detailed in all books on water analysis. The process, whilst fairly reliable in the case of lime-hardness and for control work in water of known composition, is otherwise erratic and misleading. It is therefore preferable to proceed as outlined below (" Analysis of the mineral constituents of water ").

Combined chlorine. A few drops of neutral potassium chromate solution are added to 50 cc. of the sample, which is then titrated with standard silver nitrate solution,[11] until a faint but permanent reddish tinge is attained. (In the presence of free acid or free alkali the water should first be suitably treated.)

Metallic contamination (with special reference to the presence of lead). 50 cc. of the clear sample is acidified with 3 drops of pure conc. acetic acid, and 2 cc. of freshly-prepared saturated solution of hydrogen sulphide added. In case sufficient lead is present to give a brown coloration, it is compared with the results obtained from varying amounts of a standard lead solution similarly treated. Before issuing a negative report, it is advisable whenever the volume of sample allows, to evaporate 250 cc. (or preferably 500 cc.) after acidifying with pure acetic acid, to 50 cc. and repeat the above test. Estimations of copper, tin, zinc, etc., require a larger amount of sample.

Total acidity. 50 to 100 cc. of the sample is titrated with $N/50$ sodium carbonate solution, using phenolphthalein as indicator, until the solution just turns pink. The result is expressed in terms of calcium carbonate. If the presence of free mineral acid is suspected, the test is repeated, using methyl orange as indicator.

Analysis of the mineral constituents of water follows along the usual lines, and will only be outlined for a restricted analysis, which may be suitably amplified in case a complete mineral analysis is desired. The alkalinity (which is Temporary

Hardness unless carbonate of soda is present) is determined by titrating a volume of the water, varying from 100 cc. to 500 cc. according to circumstances, with standard acid to exact neutrality, using methyl orange as indicator. The result is expressed in terms of $CaCO_3$. The Total Hardness is now ascertained by evaporating this neutral solution to a small bulk in a platinum dish after the addition of a known excess of standard alkali, consisting of equimolecular proportions of Na_2CO_3 and $NaOH$; the residue is taken up with small quantities of hot distilled water, filtered and washed until all free alkali is removed. The excess of alkali in the filtrate is now determined, and the Total Hardness, in terms of $CaCO_3$, calculated accordingly; after acidifying, the sulphate is estimated. Alternatively, the Total Hardness is determined by dissolving the residue in standard acid and titrating the excess as usual. The titrated dissolved residue may be used for the estimation of iron, aluminium, calcium and magnesium. The sample is sometimes examined for phosphate, which, if present, might be of significance, but this is generally unnecessary.

Microscopical examination of the deposit.

Occasionally enumeration of the various types of higher organisms present in a water is required; it is generally only necessary to classify plankton, of which the presence indicates sewage or allied organic contamination, or explains the origin of some specific complaint, such as odour or taste. The former involves a more elaborate technique, concentration of the particulate matter, micrometric counts in a large number of fields, etc. In routine examination the procedure is to tap off the deposit, accumulated overnight, from the separator (referred to under " Chemical Analysis ") into one or more small centrifugal tubes, which are then whirled at a high speed. Several clean slides are prepared by taking up portions of the deposit with clean drawn-out tubing in the usual manner. The preparations are loosely covered and immediately examined, first with the lower and then with the higher powers.

(a) The only higher bacterial forms of significance are the filamentous (thread) organisms, some of which indicate a high degree of recent organic contamination. Typical examples are *Sphærotilus natans*, *Cladothrix*, *Leptothrix* and *Crenothrix* forms, the two latter being more or less highly coloured, due to fixation of iron and/or manganese.

(b) The non-bacterial forms include diatomaceæ, chlorophyceæ, cyanophyceæ, the higher fungi, protozoa, crustacea, etc. The presence of many of these, for example, *Leptomitus*

(included in the higher fungi), ciliate infusoria, of which *Paramecium* and *Vorticella* may be taken as typical, flagellate organisms (*Euglena*, *Peridinium*, etc.), *Oscillatoria* and *Anabœna*, throw considerable light on the recent history of the water, and indicate potential, if not actual, danger. Whether the presence of one or other type can be definitely ascribed to sewage pollution is of secondary importance to the fact that they are usually associated with an unsatisfactory amount of fermentable organic matter. Certain of the more highly organised forms, for example, crustaceæ, function as purifying agents, and, whilst they may be harmless in themselves, often appreciably assist in the general diagnosis. To express a definite opinion that water has suffered pollution by sewage is not easy from the microscopical characteristic of the deposit, unless such pollution is gross, or the amount of sample available is very large. The presence of the ova or larvæ of human endoparasites, including *Tænia solium*, *Bothriocephalus*, *Trichocephalus dispar*, *Anchylostomum duodenale*, etc., is quite possible and must not be overlooked. As typical of the Vermes, *Anguillula* are not necessarily associated with sewage pollution, although frequently met with in waters of doubtful character. Again, the seasonal inoculation of supplies with such specific organisms as *Asterionella* (*diatomaceæ*), *Volvox*, *Pandorina*, *Anabœna*, etc. (algal type) and *Uroglena*, *Peridinium*, etc., among the protozoa, frequently gives rise to objectionable tastes and odours. Others, for example, *Protococcus* and *Hæmatococcus pluvialis*, may cause entire discoloration of storage supplies. Such conditions are usually overcome by the carefully-controlled introduction of algicidal agents of high potency (*e.g.*, copper sulphate) without interfering, in any way, with the general quality of the water.

(c) Little significance is generally attached to the classification of amorphous matter, which includes mineral and organic debris, vegetable fibre and tissue, etc.

Bacteriological examination.

Whilst the correct interpretation of the results of chemical analysis affords valuable information with respect to the character of the water and its past history, the data so far obtained is insufficient for the certification of any individual water as fit for use as a public supply. In order to be in a position to return the water as safe or otherwise for dietetic purposes, it is essential that it should be submitted to a more or less complete bacteriological examination. Such examination consists of : (a) the enumeration of the total number of organisms capable of growing on gelatin medium at 20°C., and on agar-agar medium at 37°C.; (b) the determination of

the presence or absence of the bacillus *Coli communis*, which, while not necessarily pathogenic in itself, is taken as indicative of the presence of organisms of intestinal origin; moreover, its identification is comparatively a simple matter. The usual procedure may be outlined as follows :—

Total count. Gelatin medium at 20°C. 10 cc. of the G.P.B. medium,[12] contained in a test-tube (6 in. by ¾ in.) plugged with cotton-wool, is melted by placing the tube in water for a few minutes at a temperature of approximately 40°C., cooled to about 30°C., and a suitable volume of the water, diluted if necessary 1 : 10 or 1 : 100 with sterile distilled water, is added by means of a sterile graduated pipette. The cotton-wool plug is temporarily replaced, and the inoculated media thoroughly mixed by rolling the tube in a vertical position between the palms of the hands. The plug is then ignited and withdrawn by forceps, the tube being held in a slightly inclined position and the contents poured steadily into the lower plate of a sterile Petri dish of suitable size, holding the cover over the dish to avoid atmospheric contamination. The cover of the Petri dish is replaced, and the dish at once transferred to a levelled slab, at as low a temperature as possible to hasten solidification of the medium. The inoculated Petri dishes are incubated at 20°C. for 48 hrs. The number of colonies is counted on the plate, giving a reasonable field, and if desired, distinction is drawn between liquefying and non-liquefying colonies. In counting the colonies, Wolfhugel's or similar type of apparatus is used; the Petri dish is placed on the enumerating plate or disc, the cover removed and replaced by a plain, thin, sterilised piece of glass. A magnifying glass is used to pick out the colonies whenever necessary, and observations are made as to appearance, etc. The results are recorded in terms of " organisms per cc."

Agar-agar medium at 37°C.[13] The procedure adopted is similar to that described above, with the exception that, on account of the higher melting-point, the agar tubes are first immersed in water at approximately 60°C., and then cooled to about 43°C. before inoculation with the sample under examination. Means must also be adopted for avoiding the condensation of water on the upper plate of the Petri dish during incubation at the higher temperature; this may be overcome by employing a different type of Petri dish, in which the upper cover is made of porous material instead of glass, or the Petri dish may be inverted in the incubator and a special clip used which allows a space for the release of the moisture lost by evaporation. The organisms are usually enumerated after 48 hrs. incubation, and the results recorded in terms of " organisms per cc." as before.

Determination of the presence of B. Coli communis.

Presumptive tests. Various preliminary methods for this purpose are employed, of which the two following examples may be given :—

(1) Inoculation of 0·1, 1·0, 10·0, and 100 cc. in varying strengths of lactose-litmus broth contained either in ordinary test-tubes in which are placed small Durham fermentation tubes for the collection of any gas evolved, or in V-shaped tubes sealed at one end, in which the gas evolved is measured in the upper closed limb of the tube. The inoculated tubes are incubated at 37°C., and examined for acidity and gas production at the end of 24 and 48 hrs. incubation. The general practice is to return the results as positive presumptive evidence where both acid and gas are manifest after 24 hrs. incubation. If gas is not evolved until 48 hrs. have elapsed, the results are treated as doubtful, and should be subject to confirmatory tests yielding positive results.

(2) Inoculation of corresponding volumes of the water in tubes with internal Durham tubes, containing either single, double or triple strength McConkey solution,[14] depending on the volume of water tested. This is the method adopted by Houston for the determination of presumptive B. Coli. The presence of acid or gas is noted at the end of 24 and 48 hrs. incubation.

If these presumptive tests yield negative results with volumes of the water exceeding 10 cc., it is not usual to proceed further, but if positive results are obtained with 10 cc. or less of the water, such results should be corroborated by the application of confirmatory tests. In general practice it has been found that 90% of positive presumptive tests are confirmed as typical B. Coli, and consequently many observers rely entirely on the presumptive test. The various confirmatory methods employed include a series of fermentation tests on various substances, *e.g.*, mannitol, dulcitol, etc. One of the simplest confirmatory tests is to take the litmus-broth tube or the McConkey solution tube which gives positive results with the least volume of water, and re-inoculate into litmus-lactose agar,[15] plate and re-incubate. Any typical acid organisms may then be examined microscopically, picked out and re-inoculated into the original tubes used for the presumptive test, and the result noted after 24 hrs. further incubation. The final results may be recorded as, for example, "absent in 1 cc., present in 10 cc."; "absent in 0·1 cc., present in 1cc.," etc.

Standard solutions.

(1) **Standard ammonium chloride solution.** 3·82 grm. of

ammonium chloride is dissolved in 1000 cc. of ammonia-free distilled water.

1 cc. = 0·001 grm. N. (stock solution).

10 cc. of the above solution is diluted to a litre with ammonia-free distilled water.

1 cc. = 0·01 mgrm. N.

(2) Nessler's solution. 13 grm. of mercuric chloride dissolved in 500 cc. of distilled water is mixed with 35 grm. of potassium iodide in 100 cc. of distilled water, and saturated mercuric chloride solution is added until a slight permanent precipitate of mercuric iodide is obtained. 120 grm. of sodium hydroxide dissolved in 200 cc. of water is added cold, and the solution made up to 1 litre with distilled water.

(3) Alkaline potassium permanganate. 200 grm. of potassium hydroxide dissolved in 500 cc. of water is mixed with a solution of 8 grm. of potassium permanganate in 750 cc. of water, and the solution evaporated to 1000 cc.

(4) Sulphanilic acid. 1 grm. is heated on a water-bath with 15 cc. of glacial acetic acid and 50 cc. of distilled water, and the solution is diluted to 285 c.. with distilled water.

(5) α-Naphthylamine acetate. 0·2 grm. is treated as under sulphanilic acid, diluting the solution to 325 cc.

(6) Standard sodium nitrite solution. 0·25 grm. of pure anhydrous sodium nitrite is dissolved in 500 cc. of distilled water, and the strength determined by titration with N/80 potassium permanganate solution. From this stock solution the working solution is prepared so that :

1 cc. = 0·001 mgrm. N.

The stock solution is preserved in a dark-coloured bottle.

(7) Phenol disulphonic acid. 15 grm. of pure phenol is heated for 6 hrs. on a water-bath with 100 cc. of pure concentrated sulphuric acid.

(8) Standard nitrate solution. 0·722 grm. of pure potassium nitrate is dissolved in 1000 cc. of distilled water. 100 cc. of this solution, evaporated just to dryness in a small porcelain dish, is treated with 2 cc. of the phenol disulphonic acid, mixing thoroughly with a glass rod, and the solution is diluted to 1000 cc. with distilled water.

1 cc. = 0·01 mgrm. N.

(9) Dilute sulphuric acid for oxygen absorption test. One volume of pure sulphuric acid is diluted with three volumes of distilled water, and a very small amount of potassium permanganate solution added cautiously until faintly pink.

(10) Standard solution of potassium permanganate for oxygen absorption test. 0·395 grm. of pure potassium permanganate is dissolved in 1000 cc. of distilled water.

1 cc. = 0·1 mgrm. available oxygen.

(11) Standard solution of silver nitrate. 4·791 grm. of pure silver nitrate is dissolved in 1000 cc. of distilled water.

1 cc. = 0·001 grm. Cl.

(12) Gelatin medium (G.P.B.). A litre of broth is prepared by gently boiling 1 lb. of lean beef, chopped into small pieces, with a litre of water for 3 hrs. When cool, the fat is removed, and the mixture filtered and made up to a litre. 10grm. of peptone, 5 grm. of salt, and, gradually, 120 grm. of gelatin are added to the boiling solution until dissolved, when it is made alkaline by addition of 11 cc. of 20% sodium hydroxide solution. White-of-egg is added to the lukewarm solution, which is then sterilised for 45 mins. by steaming, and allowed to stand for 15 mins. before filtering into tubes (about 12 cc. per tube). The tubes are re-sterilised for 45 mins. on two consecutive days.

(13) Agar-agar medium (A.P.B.). 20 grm. of agar (fibre) is cleaned by treatment with 500 cc. of water and 2·5 cc. of glacial acetic acid for 1 hr., and then washed thoroughly until acid-free. A litre of broth is boiled with peptone and salt as under (12), the agar introduced, and the mixture autoclaved for 30 mins. The lukewarm solution is made alkaline with 6 cc. of 20% sodium hydroxide solution, clarified as under (12), autoclaved for 45 mins., filtered through a hot-water filter, and tubed for slopes and plates. The tubes are re-sterilised for 45 mins. on two successive days.

(14) McConkey medium. The quantities of ingredients used in the preparation of the various strengths of this medium are as follows :—

	Single strength.	Double strength.	Triple strength.
Peptone, grm.	20	40	100
Lactose, grm.	10	20	50
Bile salt, grm.	5	10	25
Litmus, 1%, cc.	100	200	500
Water, cc.	900	800	500
NaOH soln., 20%, cc.	1.25	2.0	3.0

The 1% litmus solution is prepared by digesting 2 oz. of powdered litmus with successive quantities of hot water, decanting the solution; the extract is evaporated, and any carbonate present decomposed with a slight excess of acetic acid; the evaporation is continued until the mass is pasty, and the azolitmin precipitated with 200 cc. of 90% alcohol; the precipitate is filtered off, washed well wtih alcohol, dissolved in warm distilled water, and made up to 500 cc. Solution is effected by heating the solid constituents with the water, filtering, and then adding the alkali and litmus solution. The medium is distributed into Durham fermenta-

tion tubes, and sterilised on three successive days by 30 mins. steaming. In the test 10 cc. of the single-strength medium is used for 1 cc. of the sample; 10 cc. of the double-strength medium for 10 cc. of the sample; and 25 cc. of the triple-strength medium for 100 cc. of the sample.

(15) *Litmus-lactose-agar medium.* This medium is prepared as under nutrient agar (13), with the exception that 1% of lactose is added prior to sterilisation, and the medium neutralised, using phenol-phthalein as indicator. 1 cc. of sterilised litmus solution is placed in the Petri dish when plating.

Interpretation of Results.

Owing to the extreme difficulty of distinguishing between nitrogen of vegetable origin and that due to sewage or allied contamination, great care must be exercised in the interpretation of the results of the chemical analysis of water, and particularly so in the absence of information relating to the source of the water. For this reason very little value is to be attached to tables purporting to lay down so-called limits of impurity, as measured by the amount of oxidisable matter determined by the oxygen absorbed from acid permanganate of potash, and/or the amount of albuminous matter gauged from the albuminoid ammonia determination. Information obtained from the results of chemical examination of a large number of waters from widely different gathering grounds, shows that, in certain instances, waters which are of a high degree of organic purity may not be bacteriologically sound and *vice versâ*. Waters free from sewage or similar impurity may yield relatively high figures for oxidisable matter and albuminoid ammonia derived from purely vegetable sources.

It follows that, before the analyst expresses a definite opinion upon a sample of water (unless he is in possession of special knowledge as to its history from source to consumer), the chemical results should be correlated with those obtained from a bacteriological examination. In considering the data given by the latter, the total count of the organisms do not necessarily indicate the origin of the water, and greater significance must be attached to the type of organism present. On the other hand, a high count of organisms developing at blood-heat must be looked upon with suspicion. It is desirable that, in the case of a public water supply, the total number of organisms growing in agar-agar medium should not exceed 10 per cc. The same limit should be observed in deep wells, whilst, if the water is of surface origin, a maximum of 100 per cc. should not be exceeded. So far as the B. Coli organism is concerned, in the case of deep well water it should not be present in quantities less than 100 cc., and, for surface

or shallow well supplies, a reasonably safe standard requires that it should be absent in quantities of 10 cc. or less.

Sewage and Effluent Analysis.

The routine examination of sewage includes much of the data already outlined in the previous section, *e.g.*, estimation of free and saline ammonia, albuminoid ammonia, nitrogen in mineralised form, oxygen absorbed from acid permanganate in 4 hrs., combined chlorine, etc. It is therefore only necessary to modify slightly the methods in respect of the amounts of the sample taken for the several determinations. If, as a routine measure, it is desired to test the efficiency of a sewage treatment, it is usual to base the percentage of purification obtained upon either the respective yields of albuminoid ammonia from untreated sewage and effluent, or the reduction in oxidisable matter indicated by the permanganate test.

With respect to the requirements of the Rivers Pollution Prevention Act, however, the two deciding factors of the quality of a sewage effluent—other than the possible presence of toxic bodies, etc.—are (1) the amount of suspended solids present, and (2) the amount of dissolved oxygen which the sample is capable of abstracting from tap-water (after suitable dilution) on incubation for five days at 18°C. After careful deliberation, the Royal Commissioners, in their eighth report on Sewage Disposal, recommended that the former should not exceed three parts, and the latter two parts, per 100,000 of the effluent. The methods of determination are detailed in that Report, Part 2, Sections 2 and 3. The tests recommended were briefly :

Suspended solids. A suitable quantity of the effluent is filtered through a Gooch crucible fitted with an asbestos mat (which must take up some of the colloids present). Non-volatile solids are determined by ignition in the usual manner.

Dissolved Oxygen. The shaken sample is mixed quietly with 4 vols. of aerated tap-water. One portion is transferred to stoppered bottle, which is *completely* filled and is placed in an incubator at 18°C. for 5 days, at the end of which period the dissolved oxygen remaining is determined. The dissolved oxygen content of the remaining portion of the sample is immediately ascertained by the Winkler method (Rideal-Stewart modification), which depends upon the oxidation of manganese hydroxide to manganous acid and the iodimetric determination of the amount of oxygen taken up by the addition of hydrochloric acid and potassium iodide to the solution ; the liberated iodine is titrated with standard sodium thiosulphate. The difference between the initial and final

oxygen contents, multiplied by 5, gives the amount of dissolved oxygen taken up in this period.

In general practice the procedure laid down in that Report may with advantage be simplified. For example, centrifugal methods may be employed for the estimation of particulate suspended matter, thus avoiding the inclusion of colloids, part of which may be included in filtration processes. Further, in the absence of nitrites or other active reducing bodies, preliminary acidification and oxidation, with subsequent removal of excess potassium permanganate, may be omitted, whilst it is permissible, when the hydrochloric acid has completely dissolved the manganese hydroxides, to transfer the whole of the contents of the bottle to a capacious flask for titration with the thiosulphate

Whilst strictly legal standards are non-existent, it will be obvious from the above remarks that the necessary requirements are as follows : An effluent must contain neither mineral acid, caustic alkali, antiseptic nor poisonous substance ; it must be reasonably free from suspended matter; and it must be sufficiently stable, in a bio-chemical sense, as not to affect prejudicially the character of the stream into which it is discharged.

The waste waters from manufacturing premises vary so profoundly in character that, beyond some elasticity in the permissible amount of suspended solids (as compared with sewage effluents), it is more necessary to stress the importance of taking local circumstances into full consideration, and treating each case on its merits, than to attempt to define limits of composition.

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FUELS AND ILLUMINANTS.

H. Moore, M.Sc. Tech.

Absolute Heating Effect or Calorific Power.

The approximate calorific power may be calculated from the ultimate analysis by means of the formula :

$$W = \frac{34500 \, (H - \frac{1}{8} O) + 8137 \, C}{100}$$

or, taking into account the latent heat of vaporisation required for the hygroscopic water :

$$W = \frac{34500 \, (H - \frac{1}{8} O) + 8137 \, C - 600 \, H_2O}{100}$$

The figure 34500 calories, used in this formula, is obtained with hydrogen when the products of combustion contain the water in the liquid state. In practice, the water formed by combustion leaves the combustion zone in the state of steam. Working on the latter assumption, a lower calorific value is obtained. When allowance has been made for the latent heat of vaporisation and the specific heat it is found that one gram of steam carries away approximately 600 cal. of heat. As one gram of hydrogen forms nine grams of water, the loss per gram hydrogen will be 5,400 cal. ; therefore $34500 - 5400 = 29100$ calories will be available. If the sulphur content of a fuel be known, the calorific power of its combustion to SO_2 should be taken into account (2200 cal. per gram) ; as, however, a portion is burnt to SO_3 (3300 cal.) it is preferable to consider the value as 2500 cal.

The formula then becomes

$$W = \frac{8137 \, C + 29100 \, (H - \frac{1}{8} O) + 2500 \, S - 600 \, H_2O}{100}$$

This formula is only approximate, as the carbon and hydrogen are not present as elements but in combination ; moreover, the the oxygen is not present in the form of water.

$W/636$ is the theoretical evaporating power, that is the weight of water at 0°C. which a given weight of fuel will convert into steam at 100°C., assuming that the carbon and hydrogen are burnt to CO_2 and H_2O.

The most reliable and accurate method of determining the calorific value is by burning the substance and measuring the heat evolved in a calorimeter. The best instrument for

this purpose is the bomb calorimeter originally devised by Berthelot. Many forms of this instrument are at present available; they are all similar in the more important features. The bomb calorimeter consists of a strong steel chamber, the inside of which is coated with platinum or enamel. This vessel must be capable of standing a pressure of at least 50 atmospheres (750 lbs. per square inch) and forms the chamber in which the combustion takes place. The bomb is filled with oxygen at a pressure of approximately 20 atmospheres (300 lbs. per square inch), the ignition of the fuel being obtained by fusing a thin platinum or iron wire by means of an electric current.
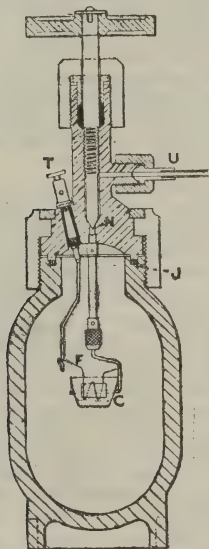
Section of Mahler-Cook Bomb.

T = Insulated Terminal.	N = Needle Valve.
J = Lead Joint.	C = Crucible.
F = Fuse Wire.	U = Union to Oxygen Supply.

The bomb is immersed in water contained in a vessel, the whole being then placed in a case provided with special devices to obtain the thermal insulation of the vessel. The container is provided with a stirring arrangement and a special Beckman thermometer (graduated to $\frac{1}{100}°$ C). By taking readings of the thermometer before and after combustion the rise in temperature of the bomb, water and container is found. As the bomb and container are never perfectly insulated from their surroundings an interchange of heat from one to the other takes place during the experiment. This heat is mainly transferred by radiation, and in order to obtain accurate results it is necessary to make a correction for this when calculating the calorific power of a fuel from the results of an experiment. In order to simplify the calculation and to ensure accuracy, it is most satisfactory to wait until the temperature of the container becomes constant before firing the charge. Readings are taken at regular intervals until the temperature of the container is falling at a uniform rate. A satisfactory method of calculating the radiation correction is by means of the following formula :

Correction $= K \ (t_2 - t_1 + t_3 - t_1 + t_4 - t_1 \ \ldots \ldots \ldots + t_n - t_1)$;
   where t_1, t_2, t_3, etc., are the initial, second, third, etc., temperature readings,
   t_n is the maximum temperature reading,
   K is the decrease in temperature per interval after maximum temperature.

It is also necessary to make a correction for sulphur if it be present in the fuel. The sulphur dioxide found in a bomb calorimeter reacts with oxygen and water, thus generating more heat than under normal conditions of combustion. The correction to be subtracted from the calculated calorific power is 22·5 calories for each 1% of sulphur present in the fuel.

A further deduction must be made of 227 calories for each gram of nitric acid present in the bomb at the end of the experiment. Referring to tests of coal, Brame states that the nitric acid correction is usually of the order of 15 calories, and the sulphur 20 calories.

In determining the calorific value of gases special calorimeters are employed. A suitable example of this type of instrument is the Junker calorimeter. This consists of a chamber through which a measured quantity of water flows ; the chamber is heated by a Bunsen burner consuming the gas at a measured rate. The chamber is so arranged that a very high thermal efficiency is obtained, that is to say, the heat of the flame is almost completely transferred to the water. If G

be the quantity of gas burnt (in litres), W the weight of water in grams leaving the calorimeter, T the temperature difference between inlet and outlet water, the calorific value of the gas is:

$$H = \frac{W.T}{G} \text{ calories.}$$

If the products of combustion contain the water in the form of steam, then

$$H = \frac{W.T - 600 \, H_2O}{G} \text{ calories.}$$

If the pressure (h) and the temperature (t) of the gas are taken into consideration, in order to obtain the results in terms of 15°C. and 760 mm. the following formula is employed:

$$H = \frac{W.T - 600 \, H_2O}{G} \times \frac{273 + t}{288} \times \frac{760}{h}$$

In Britain it is usual to state results in B.Th.U. per cubic ft. The results are determined in calories per cubic ft., and the calories then calculated to B.Th.U. by multiplying by 3·968.

Calorific Intensity.

The calorific intensity may be determined by a pyrometer, or calculated from the calorific value and the specific heats of the products. The former is the more satisfactory method, but the results obtained vary considerably according to the conditions under which combustion takes place. The specific heats of the products of combustion are not known to any close degree of accuracy. The theoretical temperatures obtained by calculation are also affected by loss of heat due to conduction and radiation, and by dissociation of the products of combustion at high temperatures.

Air Required for Combustion. (A.)

The theoretical weight of air required to burn one kilogram of fuel consisting of C, H and O can be obtained from the following equation:

$$A = 0·0116 \, [C + 3 \, (H - \tfrac{1}{8} \, O)] \, Kg.$$

where C, H, and O are grams of carbon, hydrogen, and oxygen per kilogram of fuel.

For heating with coal with a natural draught, the amount of air required may be taken as 2A, with wood or with forced draught 1½A. For gas firing the figure 1A may be closely approximated.

Calorific Properties of Various Solid Fuels.

Substance.		Calorific Power. calories.	B. Th. U.	Observed by
Scotch peat briquettes (16 % H$_2$O)		4,754	8,558	F. Mollwo Perkin.
Coke from Scotch peat		7,600	13,680	,, ,,
Oak (containing 13.3 % H$_2$O) ..		3,990	7,182	Gottlieb.
,,	11.8 ,, ..	4,155	7,479	,,
Yoke elm ,,	12.2 ,, ..	4,151	7,490	,,
Beech ,,	12.95 ,, ..	4,168	7,502	,,
,,	13.95 ,, ..	4,101	7,382	,,
,,	13.75 ,, ..	4,114	7,405	,,
Birch ,,	11.83 ,, ..	4,207	7,573	,,
Pine ,,	12.17 ,, ..	4,422	7,960	,,
Fir ,,	11.80 ,, ..	4,485	8,073	,,
Anthracite		8,400	15,120	Dosch.
Anthracite from Westphalia ..		7,575	13,635	Langbein.
Short flame sinter coal		8,200	14,760	Dosch.
Kentucky coal (U.S.A.)		7,785	14,013	U.S. Geological Survey.
Illinois coal (U.S.A.)		7,056	12.701	,, ,, ,,
Pennsylvania coal (U.S.A.) ..		7,875	14,175	,, ,, ,.
Coke		6,900	12,420	Dosch.
Coke		6,919	12,454	Langbein.
Lignite		4,000	7,200	Dosch.
Earthy lignite		3,000	5,400	,,
Lignite briquettes		4,668	8,402	Langbein.
Lignite from Saxony (moist) ..		2,622	4,720	,,
Peat		4,230	7,614	,,
Sawdust briquettes		4,065	7,317	,,
Asphaltum (extracted from petroleum)		9,550	17,190	H. Moore.
Dry peat (average from bog) ..		4,490 —6,140	8,100 —11,000	Anderson and Dillner.
Dry reed grass peat		4,140 —5,460	7,450 —9,820	,, ,,
Dry mud peat		4,360 —4,560	7,825 —8,200	,, ,,

OXYGEN AND AIR REQUIRED TO BURN "N" PARTS OF VARIOUS FUELS.

N =	1	2	3	4	5	6	7	8	9
N Kg C require Kg.O.	2.6667	5.3333	8.0000	10.667	13.333	16.000	18.667	21.333	24.000
Kg.Air	11.5011	23.002	34.503	46.004	57.505	69.006	80.508	92.009	103.51
Cb.m.O.	1.8643	3.7286	5.5928	7.4571	9.3214	11.186	13.050	14.914	16.778
Cb.m.Air	8.8944	17.789	26.683	35.578	44.172	53.367	62.261	71.156	80.050
N Kg H require Kg.O.	7.98	15.96	23.94	25.92	39.90	47.88	55.86	63.84	71.82
Kg.Air	34.4170	68.834	103.25	137.67	172.08	206.50	240.92	275.34	309.75
Cb.m.O.	5.5788	11.158	16.737	23.315	27.894	33.473	39.032	44.631	50.210
Cb.m.Air	26.5984	53.197	79.795	106.39	132.99	159.59	186.19	212.79	239.39
N Kg CO require Kg.O.	0.5714	1.1429	1.7143	2.2857	2.8571	3.4286	4.0000	4.5714	5.1429
Kg.Air	2.4645	4.9291	7.3936	9.8582	12.323	14.787	17.252	19.716	22.181
Cb.m.O.	0.3995	0.7990	1.1985	1.5979	1.9974	2.3969	2.7964	3.1959	3.5954
Cb.m.Air	1.9046	3.8093	5.7139	7.6186	9.5232	11.428	13.333	15.237	17.142
N Kg CH₄ require Kg.O.	3.9975	7.9950	11.992	15.900	19.987	23.985	27.982	31.980	35.978
Kg.Air	17.2410	34.482	51.723	68.964	86.205	103.45	120.69	137.93	155.17
Cb.m.O.	2.7947	5.5893	8.3840	11.179	13.973	16.769	19.563	22.357	25.152
Cb.m.Air	13.3291	26.658	39.987	53.317	66.646	79.975	92.304	106.63	119.96
N Kg C₂H₄ require Kg.O	3.4273	6.8547	10.282	13.719	17.137	20.564	23.991	27.419	30.846
Kg.Air	14.7820	29.564	44.346	59.128	73.910	89.692	103.47	118.26	133.04
Cb.m.O.	2.3961	4.7921	7.1882	9.5843	11.980	14.376	16.772	19.169	21.565
Cb.m.Air	11.4280	22.856	34.284	45.712	57.140	68.568	79.996	91.424	102.86
N Cbm H require Kg.O.	0.7174	1.4348	2.1522	2.8696	3.5870	4.3044	5.0218	5.7392	6.4566
Kg.Air	3.0941	7.1881	9.2822	12.376	15.470	18.564	21.658	24.752	27.847
Cb.m.O.	0.5015	1.0031	1.5046	2.0061	2.5077	3.0092	3.5107	4.0123	4.5138
Cb.m.Air	2.3912	4.7823	7.1735	9.5647	11.956	14.347	16.738	19.129	21.521
N Cbm CO require Kg.O.	0.7174	1.4349	2.1523	2.8697	3.5872	4.3046	5.0220	5.7394	6.4569
Kg.Air	3.0942	6.1885	9.2827	12.377	15.471	18.565	21.660	24.754	27.848
Cb.m.O.	0.5016	1.0031	1.5047	2.0062	2.5078	3.0094	3.5109	4.0125	4.5140
Cb.m.Air	2.3913	4.7826	1.1739	9.5652	11.957	14.348	16.739	19.130	21.522
N Cbm CH₄ require Kg.O.	2.8696	5.7391	8.6087	11.478	14.348	17.217	20.087	22.957	25.826
Kg.Air	12.3763	24.753	37.129	49.505	61.882	74.258	86.634	99.010	111.39
Cb.m.O.	2.0061	4.0123	6.0184	8.0245	10.031	12.037	14.043	16.049	18.055
Cb.m.Air	9.5682	19.136	28.705	38.273	47.841	57.409	66.978	76.546	86.114
N Cbm C₂H₄ require Kg.O.	4.3044	8.6087	12.913	17.217	21.522	25.826	30.131	34.435	38.739
Kg.Air	18.5645	37.129	55.693	74.258	92.822	111.39	129.95	148.52	167.08
Cb.m.O.	3.0092	6.0184	9.0276	12.037	15.046	18.055	21.064	24.074	27.083
Cb.m.Air	14.3524	28.705	43.057	57.409	71.762	86.114	100.47	114.82	128.27

HEAT OF COMBUSTION WITH OXYGEN OR AIR

The following determinations were made by Berthelot (B) Favre and Silberman (F), Thomsen (Th) and Stohman (St).

Substance.	Products of Combustion.	Calories K per Kilogram.	Calories K per Gram. Mol.	Observed by
Wood charcoal	CO_2	8080	96.96	F
Wood charcoal	CO_2	8137	97.65	B
Sugar charcoal	CO_2	8040	—	F
Retort graphite	CO_2	8047	96.57	F
Blast furnace graphite	CO_2	7762	—	F
Blast furnace graphite	CO_2	7901	94.81	B
Natural graphite	CO_2	7997	—	F
Carbon monoxide	CO_2	2403	67.28	F
Carbon monoxide	CO_2	2440	68.34	B
Wood charcoal	CO	2473	29.7	F
Wood charcoal	CO	2442	29.3	B
Hydrogen	H_2O liquid	34462	68.9	F
Hydrogen	H_2O liquid	34180	68.36	Th
Hydrogen	H_2O steam	28800	57.4*	Th
Hydrogen	H_2O steam	29150	58.3*	B
Methane CH_4	$CO_2 + H_2O$ liquid	13063	209.0	F
Methane CH_4	$CO_2 + H_2O$ liquid	13344	213.5	B
Methane CH_4	$CO_2 + H_2O$ steam	12066	191.7	B
Acetylene C_2H_2	$CO_2 + H_2O$ liquid	11927	318.1	B
Acetylene C_2H_2	$CO_2 + H_2O$ steam	11527	299.7	Th
Ethylene C_2H_4	$CO_2 + H_2O$ liquid	11858	332.0	F
Ethylene C_2H_4	$CO_2 + H_2O$ liquid	12072	341.4	B
Ethylene C_2H_4	$CO_2 + H_2O$ steam	11293	316.2	B
Propylene C_3H_6	$CO_2 + H_2O$ liquid	11934	507.3	B
Propylene C_3H_6	$CO_2 + H_2O$ steam	11155	468.5	B
Benzene C_6H_6 (gaseous)	$CO_2 + H_2O$ liquid	10070	783.2	B
Benzene C_6H_6 (gaseous)	$CO_2 + H_2O$ steam	9650	752.6	calc.
Benzene C_6H_6 (liquid)	$CO_2 + H_2O$ liquid	—	779.8	St
Naphthalene $C_{10}H_8$	$CO_2 + H_2O$ liquid	9664	1243.0	B
Naphthalene $C_{10}H_8$	$CO_2 + H_2O$ steam	9328	1194.0	calc.
Paraffin	$CO_2 + H_2O$ liquid	11140	—	St
Paraffin	$CO_2 + H_2O$ steam	10340	—	St
Hexane C_6H_{14}	$CO_2 + H_2O$ liquid	11525	991.2	St
Hexane C_6H_{14}	$CO_2 + H_2O$ steam	10636	914.8	St
Heptane C_7H_{16}	$CO_2 + H_2O$ liquid	11375	1137.5	L
Alcohol C_2H_6O	$CO_2 + H_2O$ liquid	7184	330.5	F
Alcohol C_2H_6O	$CO_2 + H_2O$ liquid	7054	324.5	B
Glycerin $C_3H_8O_3$	$CO_2 + H_2O$ liquid	4316	397.1	St
Starch $C_6H_{10}O_5$	$CO_2 + H_2O$ liquid	4228	685.0	B
Cellulose $C_6H_{10}O_5$	$CO_2 + H_2O$ liquid	4208	682.0	B
Dextrose $C_6H_{12}O_6$	$CO_2 + H_2O$ liquid	3762	677.0	B
Cane sugar $C_{12}H_{22}O_{11}$	$CO_2 + H_2O$ liquid	3963	1355.0	B
Stearic acid	$CO_2 + H_2O$ liquid	9374	—	St
Rhombic sulphur	SO_2	2221	71.08	F
Rhombic sulphur	SO_2	2166	69.3	B
Monoclinic sulphur	SO_2	2241	71.72	Th
Carbon disulphide	$CO_2 + SO_2$	3333	253.0	B
Silicon	SiO_2	7407	207.4	B
Magnesium	MgO	6077	145.9	T
Iron	Fe_2O_3	1582	88.4	A
Copper	CuO	590	37.2	T

* The heat required to evaporate 1 kilogram of water at 0°C. is 606.5 calories K.

One kilogram of coal yields approximately 7500 Cal. As one kilogram of water requires 636 Calories (K) in order to raise to 100° C and convert it into steam, it follows that $\frac{7500}{636} = 11\cdot79$ kilograms of water should be evaporated by one kilogram of coal. In practice with a cylindrical boiler only about 6·5 kilograms, and with the best tube boiler 10 kilograms of steam are obtained.

When employing gaseous fuels much higher efficiencies can be obtained. By means of a surface combustion boiler Prof. Bone has obtained over 95% of the total heat from the fuel.

The overall thermal efficiency of an engine is the proportion which the heat converted into work bears to the total heat entering the engine.

The thermal efficiency (μ) of an engine which consumes x lbs. of fuel of calorific power W for each horse power hour is obtainable by the formula :

$$\mu = \frac{2,545}{Wx}$$

The overall thermal efficiencies of various types of engines when working under favourable conditions are approximately as follows :

Reciprocating steam engine and boiler	12%
Steam turbine and boiler	18%
Petrol engine (automobile)	22%
Gas engine with producers	24%
Gas engine with suction producer	26%
Petrol engine (aircraft)	27%
Semi-Diesel oil engine	30%
Alcohol engine	36%
Diesel oil engine	38%

MISCELLANEOUS DATA CONCERNING FUELS.

Fuel	P	Sp. Gr.	Composition in parts per thousand					i	Q	L	G	V
			C	H	O	W	R					
Air dried wood	350–450	0.6–0.8	400	40	320	200	40	0.25	2900	5.0	12	0.70
Air dried peat	250–400	0.4–0.5	420	45	225	250	60	0.35	3600	5.6	12	0.74
Lignite			700	50	200		50	0.5	6400	9.3	20	0.42
Bituminous coal	750–880	1.20–1.35	870	50	40		40		8300	11.0	23	0.31
Low grade anthracite			850	50	60		40		8100	10.7	22	0.32
Dry coal	900	1.35–1.46	750	50	150		50		6900	10.1	21	0.39
Anthracite	200–350		900	30	30		40	0.5–	8000	11.7	24	0.19
Carbonised peat	230–250		800	–	–		200	0.55	6500	9.6	20	–
Wood charcoal	400–440		930	–	–		70		7500	11.2	23	–
Coke			880	–	–		120		8080	10.6	22	–
Hydrogen	0.09		–	1000	–		–	–	28800	36.0	44	6.6
Methane	0.72		750	250	–		–	–	12066	18.0	–	1.4
Ethylene	1.26		860	140	–		–	–	11293	15.4	19	0.8
Illuminating gas	0.696		560	370	–		–	–	10600	20.0	25	2.07
Blast furnace gas	1.0		60	20	–		–	–	1070	1.0	–	0.11
Carbon monoxide	1.26		430	–	570		–	–	2403	5.2	2.2	–

P = weight of one cubic metre in kilograms.
i = coefficient of radiation.
G = weights of products of combustion in kilograms.
W = hygroscopic water.
Q = gross calorific value.
R = inorganic residue.
L = theoretical quantity of air required in kilograms.
V = increase in volume in ccs.

THE SAMPLING AND ANALYSIS OF COAL.

Sampling.

The greatest care must be taken in sampling. One spadeful of coal from each truck is taken, and the heap divided into four sections; two diagonally opposite portions are taken and the process is repeated until about one cwt. remains, when the coal is broken into small pieces (about $\frac{1}{2}$-inch cube). The parting process is continued until about 10 lbs. remain, the pieces broken up and then about 2 lbs. withdrawn for the finished sample. This sample is then ground to pass through a 60's mesh sieve.

Analysis.

(1) *Moisture.*

30 to 50 grams of coal are taken in a weighing bottle and dried in a steam-jacketed oven at 105° C. When the weight becomes constant, the water may be considered as completely driven off. Sometimes the weight will begin to increase, due to the absorption of oxygen from the air. In this case the minimum weight is to be taken.

(2) *Ash.*

About 1 gram of coal is ignited in a platinum crucible until the weight becomes constant (the process may take several hours).

(3) *Sulphur.*

This is best determined in the bomb liquor from the calorimeter determination. The liquor is first oxidised with an excess of bromine water. After driving off the excess of bromine by boiling, the sulphur may be estimated by precipitation as barium sulphate. The sulphur may also be estimated by the direct titration of the bomb liquor (after boiling to expel CO_2) with N/10 caustic soda solution, employing methyl orange as indicator. In this case a slight error is introduced due to the presence of traces of nitric acid formed during the combustion.

In cases where the bomb calorimeter is not employed it is usual to resort to fusion, as follows :

1 gram of powdered coal and 1·5 to 2 grams of a mixture of 2 parts magnesia and one part sodium carbonate are heated in a platinum crucible, the mass being continually gently stirred. The colour will become bright yellow or brown, when the contents of the crucible may be dissolved in boiling water, and any remaining sulphides oxidised by the addition of bromine water. The solution is filtered, the filtrate acidified with

hydrochloric acid, boiled until colourless, and then precipitated with barium chloride.

For the estimation of sulphur present as sulphate ($CaSO_4$) or sulphide (FeS_2), 1 gram of the powdered coal is heated with a saturated solution of bromine in caustic soda (Sp. Gr. 1·25), and the solution acidified with hydrochloric acid, treated with 20 cc. of bromine solution, heated and acidified, and the process repeated.

The solution is evaporated to dryness at 110° C. in order to render the silica insoluble, extracted with hydrochloric acid and the filtrate precipitated with barium chloride.

The sulphates may be determined in the ash. About 3 grams of ash are taken, mixed with water and heated with hydrogen peroxide or bromine, then acidified and precipitated with barium chloride.

(4) *Combustion.*

The combustion is carried out by the usual method employed for organic bodies. It is, however, necessary to pack the tube with lead chromate in order to retain the sulphur dioxide formed by the combustion of the sulphur.

(5) *Nitrogen.*

0·8 to 1 gram of the fine coal is taken and the nitrogen estimated by the Kjeldahl method (see Vol. I.).

(6) *Coke Yield.*

1 grm. of powdered coal is strongly heated for 7 mins. over a Bunsen flame 20 cm. high, in a platinum crucible 35 mm. deep and 22 mm. wide, the bottom of the crucible being 6—8 cm. from the top of the burner. The crucible is provided with a tight fitting lid, in the centre of which is a 2 mm. hole. The crucible and contents are allowed to cool for a period of 5--10 mins. and then weighed.

An alternative method is to heat the crucible in a muffle furnace until one minute after the last flame has disappeared.

(7) *Volatile matter.*

The volatile matter is estimated by difference from coke yield.

(8) *Coking power.*

This is also only a comparative test. The powdered coal is mixed with Calais sand to give a total weight of 25 grm. The mixture is heated as noted in the first method described for the estimation of volatile matter. The proportions of coal and sand are adjusted so that the button obtained will just bear a 100 grm. weight without being crushed. The coking power is the ratio of sand to coal. (The degree of fineness of the sand has a serious influence on the results of this test.)

Analyses of Coals. (Gray and Robinson).

	1	2	3	4	5	6	7	8	9	10	11	12
Carbon	62.55	65.50	68.64	69.50	72.14	73.77	74.99	74.57	77.00	76.71	78.80	85.70
Hydrogen	3.87	4.23	4.33	4.42	4.40	4.55	4.66	4.74	4.51	4.67	4.92	2.97
Sulphur	1.62	0.67	1.33	0.67	0.61	0.41	0.55	0.47	0.78	0.73	0.50	0.62
Water	8.63	7.92	8.96	9.28	8.34	7.99	7.21	6.95	2.31	1.94	2.72	3.15
Ash	11.78	10.15	6.90	5.97	4.22	1.76	2.68	1.37	7.17	8.49	4.18	3.59
Oxygen and Nitrogen ..	11.55	11.53	9.84	10.16	10.29	11.52	9.91	11.90	8.23	7.46	8.88	3.90
Coke	61.74	61.06	57.53	59.12	58.47	56.93	56.59	56.84	74.61	72.32	66.43	92.03
Fixed Carbon	49.96	50.92	50.63	53.15	54.25	55.17	53.91	55.47	67.44	63.83	62.25	88.44

1. Splint coal, Lochgelly, Fife.
2. Boiler fuel (a mixture), Fife.
3. Ell coal, Bothwell.
4. Main coal, Bothwell.
5. Poytshaw coal, Bothwell.
6. Dunfermline splint, Cowdenbeath, Pit 10.
7. Splint coal, Bothwell.
8. Dunfermline splint, Cowdenbeath Pit 7.
9. Boiler fuel, Aitken Pit, Kelty.
10. Haughrigg coking coal, Kilsyth.
11. Coking coal, Kilsyth.
12. Anthracite, Kilsyth.

Properties of Various Types of Coal.

Description	Composition (%)				Specific gravity	Calorific power calories	Evaporative power	Volatile portion	Coke yield
	C	H	O	$\frac{O}{H}$					
Dry coal with long flame (Sand coal.)	75–80	5.5–4.5	19.5–15	4–3	1.25	8000–8500	6.7–7.5	45–50	50–60 (powdery)
Long flame fat coal (Gas or sinter coal.)	80–85	5.8–5	14.2–10	3–2	1.28–1.3	8500–8800	7.6–8.3	40–32	60–80 (fused, intumesced)
Fat or furnace coal	84–89	5–5.5	11.5–5.5	2–1	1.3	8800–9300	8.4–9.2	32–26	68–74 (moderately dense, fused)
Fat coal with short flame (Coking coal.)	88–91	5.5–4.5	6.5–5.5	1	1.3–1.35	9300–9600	9.2–10	26–18	74–82 (fused, compact and blistered)
Short flame coal .. .. (Anthracite.)	90–93	4.5–4	5.5–3	1	1.35–1.4	9200–9500	9.–9.5	18–10	82–90 (sintered or powdery)

Analyses of American Beehive Oven Coke. (Koppers Co.)*

	Coke Analyses.						Coal Analyses.				
	Moisture.	True Sp. Gr.	Apparent Sp. Gr.	% cells by vol.	% cells cc. in 100 grm.	Wt., lbs. per cu. ft.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Broadford, Connellsville, Pa.	0.034	1.76	0.892	49.37	55.73	55.68	1.10	29.88	57.75	9.90	1.34
	0.053	1.74	0.926	46.92	52.35	57.81	—	31.86	59.62	8.23	0.78
Eagle, Kanawha, W. Va.	0.021	1.68	0.894	46.85	53.89	55.81	—	—	—	—	—
St. Clair, Kanawha, W. Va.	0.030	1.67	0.924	44.81	50.23	57.68	—	—	—	—	—
Quinnimont, New River	0.044	1.83	0.713	61.12	86.41	44.51	0.41	19.99	76.87	1.94	0.79
Sewell, New River, W. Va.	0.016	1.69	0.793	53.19	67.39	49.50	1.03	21.38	72.32	5.07	0.20
Stone Cliff, New River, W. Va.	0.074	1.74	0.838	51.79	62.30	52.31	—	—	—	—	—
Five Creek, New River, W. Va.	0.078	1.83	0.820	55.12	69.05	51.19	0.61	22.34	75.02	1.47	—
Rockwood, Tenn.	0.192	1.69	0.935	44.81	48.55	58.37	1.75	26.62	60.11	11.52	1.49
El Moro. Col.	0.114	1.69	0.919	45.75	50.39	57.37	1.14	29.97	56.32	12.57	—
Crested Butte, Col.	0.073	1.59	0.907	42.96	47.59	56.62	0.72	23.44	71.91	3.93	—
Leetonia, Ohio	0.047	1.49	0.770	47.59	62.23	48.09	3.00	31.50	62.35	3.15	1.40
Washington, D.C.	0.802	1.74	0.772	55.66	75.48	48.19	—	—	—	—	—

* Bacon and Hamar, "American Fuels," 1922.

Analyses of American By-Product Coke. (Koppers Co.)*

	COAL ANALYSES.					COKE ANALYSES.			
	Volatile matter.	Ash	Sulphur.	% through ⅛ in.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
Alabama (washed)	29.3	7.38	1.39	—	9.52	1.15	89.95	8.90	1.17
Alabama (washed)	28.4	8.80	0.79	74.8	7.42	0.50	88.74	10.76	0.64
Colorado	33.1	12.63	0.68	—	4.00	1.86	81.86	16.28	0.57
Pennsylvania	25.4	5.85	0.87	67.6	4.50	0.73	90.49	8.78	0.78
Washington	31.5	11.31	0.50	45.0	2.85	1.16	84.91	13.93	0.47
80% W. Va. 20% Ill.	21.0	8.12	0.87	84.0	3.61	2.07	86.41	11.52	0.73
80% W. Va. 20% Pa.	21.5	7.97	0.79	84.5	9.55	1.06	88.77	10.17	0.69
70% W. Va. 30% Ky.	23.1	6.34	0.63	86.0	5.20	1.95	89.64	8.41	0.66
40% W. Va. 60% Ky.	29.3	5.48	0.52	—	2.56	1.34	89.72	8.94	0.49
40% W. Va. 60% Pa.	28.9	6.73	0.77	85.0	4.46	1.47	88.31	10.21	0.67

* Bacon and Hamor, "American Fuels," 1922.

The Examination of Liquid Fuels.

The more important tests employed for the examination of liquid fuels depend upon their physical properties. For a full understanding of the fuel, it is also necessary to consider the chemical analysis.

Specific Gravity. The specific gravity of a liquid fuel may be determined by means of a hydrometer, specific gravity bottle, pyknometer or Mohr's balance. The temperature of the liquid must be taken into consideration. (The coefficient of cubical expansion of petroleum is ·0004 per degree Fahrenheit or ·00072 per degree Centigrade).

Flash point. The determination of the flash point of a liquid fuel may be made in an open basin or in one of the special instruments designed for this purpose. When the flash point is determined by means of an open basin it is usual to call the value the "open flash point," with the closed instruments it is referred to as the "closed flash point." For liquids which flash at temperatures below 100°C. the Abel apparatus is generally employed. When determining the flash point the instrument is heated slowly, the small flame on the cover being adjusted to the correct size, which is indicated by a small ivory knob attached to the cover. The test flame is dipped periodically until a small flame is observed to travel across the surface of the liquid. The liquid must be stirred continually during the test in order to prevent local overheating. The temperature reading on the thermometer in the inner vessel, when the flash is first observed, indicates the flash point.

Many modifications of the Abel apparatus exist, the best known being the Pensky Marten and the Gray instruments, both of which are adapted for the testing of "high flash" fuel and lubricating oils, the main difference between these and the original instrument being that in place of a water jacket they are provided with a cast-iron casing, thus enabling the temperature to be carried above the boiling point of water.

Temperature of Spontaneous Ignition or Ignition Point.

This test is of great importance with liquid fuels for internal combustion. It is of secondary interest in connection with solid fuels.

The determination is most satisfactorily made by means of Moore's ignition point tester (*J.S.C.I.*, 1917, p. 109). The instrument consists of a large block of metal into which are fitted a pyrometer thermocouple, a thermal plug for pre-heating the oxygen supply, and a platinum or nickel crucible of standard dimensions. The block is heated by a burner, and a current of dry oxygen slowly passed through the crucible. Oil is dropped into the crucible from a thin glass tube. If the temperature of the block as shown by the pyrometer is above the ignition point a sharp explosion follows shortly after the introduction of the oil. The lowest temperature at which the oil will ignite is the "ignition point."

Viscosity Several instruments are employed for the determination of viscosity. In England the Redwood viscometer is the standard appliance. On the Continent the Engler viscometer is used, whilst in the United States the Saybolt instrument is generally employed.

In order to determine the viscosity of a liquid, the viscometer is filled to the pointer, and the liquid heated to the required temperature by means of a Bunsen burner. When the temperature is attained the Bunsen burner is withdrawn or adjusted as is necessary to maintain the temperature. The ball valve is now withdrawn, allowing the liquid to discharge into a 50 cc. graduated cylinder. The time required to discharge 50 cc. of the oil is proportional to the viscosity. It is usual to state the results in terms of Redwood's units, which are based on refined rape oil, the viscosity of this liquid being considered as 100 units. In calculating this value it is necessary to correct for the specific gravity, to which the pressure upon the diaphragm is proportional.

Water. This may be estimated by several methods; in the case of tar products or tars, it is usual to heat the liquid slowly in a retort and receive the water and a small amount of oil in a small graduated cylinder. On addition of a few cc. of toluene to the distillate, the water settles out at the bottom of the cylinder and the volume can be read off directly. This method can be used with petroleum. Another means of estimating water is to mix a measured quantity of the oil with toluene and distil from a Wurtz flask, condensing the distillate and collecting in a graduated cylinder. For this estimation Schläpfer has designed a special cylinder, the lower portion of which is of reduced diameter, thus enabling more accurate readings of the water yield to be made.

The best method for the determination of water is the one recently described by Dr. E. W. Dean and D. D. Stark. For this test the apparatus consists of a 500 cc. short-necked distilling flask, A and a "distilling tube receiver" B. to the upper end of which is connected a Liebig's condenser C, the tube of which is ground off diagonally at the bottom end, to facilitate the dropping of the water into the measuring tube.

To make a determination, 100 cc. of the emulsion to be tested and 100 cc. of a solvent, such as petroleum ether, or a mixture of commercial xylol and commercial benzol, are introduced into the 500 cc. flask together with a fragment of unglazed porcelain, and the flask connected to the distilling tube receiver and condenser, the position of the diagonally-ground end of tube being as shown in sketch

Heat is applied to the flask so as to cause the mixture to distil at a rate of two to four drops per second, till all droplets of water in flask, distilling tube and condenser have disappeared, which usually takes about an hour. In case a ring of droplets appears in condenser the rate of distillation may be increased till it is swept away. The flask is then detached, and the volume of water collected in the graduated receiver is read off, taking care that the receiver shall be held in a vertical position.
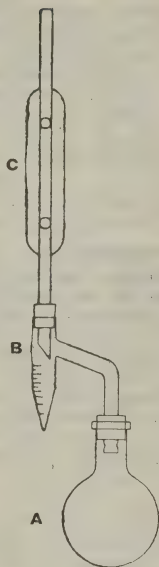
Coke Test. 100 cc. of the oil under examination are measured into a weighed Engler distillation flask, and the weight of the oil found by difference. The oil is then fractionally distilled until the temperature of the vapours is 300° C. (temperature corrected for exposed stem).

The residue in the flask is poured while hot into a 300 cc. silica beaker provided with a lid having a small central orifice. The distillation of the material in the beaker is then completed over a radial burner, the escaping vapours being carried off by the fume exhaust. Towards the end of the experiment the heating is greatly increased, the beaker being placed over the naked flame so that its base is at bright red heat, and the

flames surround the beaker so as to form an enveloping flame bath. This is continued for one minute after all visible vapours from the residue have ceased. The beaker is now cooled, and the slight amount of condensed tar on its upper internal surface burned off. The coke remains as a bright porous basal cake, detachable with ease from the silica beaker. It is then cooled in a desiccator and weighed.

Weight of oil used in grams = X.

Volume of water obtained in distillation in cc. = Y.

Weight of coke in grams = A.

Percentage of coke in dry oil = $\dfrac{A \times 100}{X - Y}$

Calorific power. The calorific power of liquid fuels can only be satisfactorily ascertained by means of a bomb calorimeter.

Distillation test. To determine the boiling points of the constituent compounds in an oil it is necessary to make a fractional distillation. For this purpose a distillation flask of the special dimensions (see sketch) recommended by Engler is employed. The thermometer is placed in the neck of the flask in such a position that the top of the thermometer bulb is level with the bottom of the side tube. 100 cc. of the liquid is distilled at the rate of two drops per second and the quantity of distillate noted every 10°. The results are best recorded by drawing a graph showing the percentage volume of distillate as a function of the temperature.
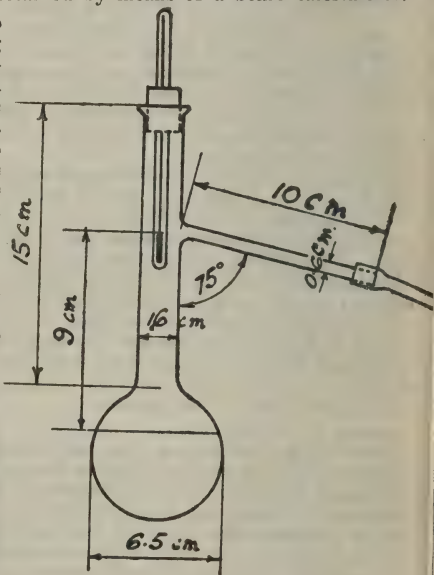
ENGLER FLASK.

A fractionating column may be employed in special cases, but the Engler method above described is more frequently used.

Asphaltum. This substance may be estimated either by evaporating the liquid in an open basin and weighing residue or by the following more satisfactory method :

5 grm. of oil are weighed into a beaker and dissolved in 25 times its volume of ethyl ether at 15°C.; 96% alcohol to the extent of $12\frac{1}{2}$ times the volume of the oil is now slowly added from a burette, the liquid being stirred continuously. After 5 hours standing at 15°C. the product is filtered and the filter washed with alcohol-ether mixture (1 : 2). The precipitate is then dissolved in benzene and the solution evaporated down in a tared dish. After repeated washing with hot alcohol, until no further precipitate of paraffin separates from the alcohol, the residue is heated to 105°C. for 15 minutes, cooled and weighed.

This test is known as the soft asphaltum test. Another test, which gives different results from the above, is known as the hard asphaltum test, the procedure in this test being as follows :

Two to five grams of an asphaltic oil, or 20 grams of an oil which is poor in asphaltum, are weighed into a one-litre flask with forty times their volume of petrol, and the mixture well shaken. The solution is filtered, and the residue washed with petrol until the filtrate on evaporation leaves no residue of oil. The precipitate is now dissolved in benzene, and the solution evaporated at 100° C. in a tarred dish.

Both these tests are applied to petroleum oils, but distilled products are free from asphaltum, therefore the test only applies to crude oils, de-petrolised crude oils, and residua.

Tar Acids. The tar acids, which mainly consist of phenol and the cresols, are determined in tar products by washing the liquid with caustic soda (40°Tw.), separating the solution (which contains the sodium salts of phenol and cresol together with free caustic soda), and acidifying the solution with sulphuric acid, when the mixed tar acids will separate from the solution. The volume of tar acids can thus be read directly by acidifying the solution in a graduated cylinder. It is usual to state the result as percentage by volume.

Cold test. The determination of the solidification point, or cold test, of liquid fuels is occasionally made. It is however preferable to cool to some definite temperature and describe the condition of the oil.

Ultimate Analysis.

The carbon, hydrogen, ash, and coke contents are determined by the usual method employed for organic substances.

Sulphur is best estimated in the liquor which condenses in the calorimeter bomb by oxidising with bromine water and precipitating as barium sulphate.

COMPOSITION AND CALORIFIC PROPERTIES OF SEVERAL SOLID AND LIQUID FUELS.

(Determined by MAHLER by means of Bomb Calorimeter.)

Description and Origin	Chemical composition				Hygroscopic water	Ash	Volatile portion without water	Calorific Power	
	% C	% H	% O	% N				Observed	Without ash & water
Long flame coal, Blancy	79.38	4.97	8.72	1.13	3.90	1.00	30.10	7865	8350
Gas coal, Commentry	80.18	5.24	7.19	0.98	3.00	3.40	37.30	7870	8408
Gas coal, Lens	83.73	5.25	6.01	1.00	1.25	3.00	29.55	8395	8744
Bituminous coal, St. Etienne	84.55	4.77	4.59	0.84	1.05	4.00	19.75	8991	8856
Anthracite, Tonkin	85.75	2.73	2.67	0.60	2.80	5.45	4.56	7828	8532
Anthracite, Pennsylvania	86.46	2.00	1.45	0.75	4.45	5.90	2.75	7484	8256
Petroleum coke, America	97.85	0.49	1.20	0.26	–	0.20	–	8057	8073
Heavy naphtha, Pennsylvania	86.89	13.11	–	–	–	–	–	10912	10912
Refined Petroleum, America	85.49	14.22	0.29	–	–	–	–	11045	–
Petroleum spirit, America	80.58	15.10	4.32	–	–	–	–	11086	–
Crude petroleum	83.01	13.84	3.10	–	–	–	–	11094	–
Heavy naphtha, Baku	86.70	12.94	–	–	–	0.30	–	10804	10842
Heavy naphtha, Novorossisk	84.91	11.54	9.46	–	–	–	–	10328	–

PROPERTIES OF TARS. (Moore.)

Description	Sp. Gr. at 15°C	H₂O	\-\-% Chemical composition\-\-\- C	H	O & N	S	Ash	Coke	Calorific Power (Dry tar) Gross	Net	Free carbon
Horizontal retort tar	1.180	1.75	91.5	5.2	2.6	0.5	0.2	24.0	9093	8645	18.2
Inclined retort tar	1.157	1.11	89.9	6.0	3.6	0.5	0.02	18.5	9096	8671	14.0
Vertical retort tar	1.089	2.25	88.0	6.8	3.8	0.6	0.03	6.1	9246	8664	1.7
Otto Hilgenstock coke oven tar	1.208	6.00	90.0	5.4	3.8	0.8	0.02	26.8	8921	8624	23.9
Simon-Carvé coke oven tar	1.090	0.50	88.1	5.6	6.1	0.2	0.07	6.0	9695	9261	traces
Chamber oven tar	1.082	1.29	88.2	6.9	4.6	0.3	traces	7.3	9229	8737	3.0
Low temperature carbonisation tar	1.058	3.00	85.8	8.1	5.5	0.9	0.11	8.2	9196	8776	2.2
Water gas tar	1.054	0.59	92.2	6.8	0.4	0.6	traces	18.7	8951	8647	6.8
Blast furnace tar	1.172	3.00	89.5	5.7	0.5	0.84	0.36	23.4	8563	^288	9.5

PROPERTIES OF MISCELLANEOUS FUEL OILS. (Moore.)

Description	Sp. Gr. (15°C)	H₂O	\-\-% Chemical composition\-\-\- C	H	O & N	S	Ash	Coke	Flash pt.	Calorific Power Gross	Net
Coal tar creosote	1.053	traces	89.7	7.4	2.23	0.66	traces	1.30	93°C.	9342	8964
Blast furnace oil	0.907	0.00	82.6	9.9	7.22	0.29	0.00	1.26	70°C.	9992	9603
Vertical retort tar oil	1.019	0.70	85.8	7.9	5.1	0.5	traces	1.65	88°C.	9189	8762
Scottish shale oil	0.945	1.6	87.00	9.50	1.04	2.35	0.11	0.18	56°C.	9917	9245
Premier tarless process oil ..	0.995	1.52	82.6	8.6	8.8	0.50	0.10	1.52	76°C.	9472	9008
Mexican fuel oil (petroleum) ..	0.952	1.00	83.6	10.9	1.5	2.85	0.17	12.2	93°C.	10350	9734
Mineralised alcohol (comcl.) ..	0.822	—	46.6	12.7	40.56	0.13	—	—	below 20°C.	6115	5421

V

Flash Points, Burning Points and Temperatures of Spontaneous Ignition. (Constam and Schläpfer).

Description.	Specific Gravity. at 15°C.	Open Flash Point. °C.	Burning Point. °C.	Temp. of Spontaneous Ignition. °C.
Crude oil from Galicia	.855	98	118	350
Gas oil from Galicia	.868	96	149	350
Roumanian gas oil	.892	87	106	350
Russian crude oil	.902	95	122	350
Texas gas oil	.892	86	103	350
Mexican crude oil	.940	58	94	350
Scotch crude oil (shale oil) ..	.942	102	114	350
African palm oil	.915	244	263	400
Coal tar oil	1.043	67	84	550
Horizontal retort tar	1.138	71	97	520
Inclined retort tar	1.157	68	74	500
Vertical retort tar	1.057	74	95	520
Coke oven tar	1.140	92	108	600
Water gas tar	.968	92	96	under 350°

Flash Point Corrections for Barometric Pressure.

mm.	Flash Points °C.												
685	16.4	16.9	17.4	17.9	18.4	18.9	19.4	19.9	20.4	20.9	21.4	21.9	22.4
690	16.6	17.1	17.6	18.1	18.6	19.1	19.6	20.1	20.6	21.1	21.6	22.1	22.6
695	16.7	17.2	17.7	18.2	18.7	19.2	19.7	20.2	20.7	21.2	21.7	22.2	22.7
700	16.9	17.4	17.9	18.4	18.9	19.4	19.9	20.4	20.9	21.4	21.9	22.4	22.9
705	17.1	17.6	18.1	18.6	19.1	19.6	20.1	20.6	21.1	21.6	22.1	22.6	23.1
710	17.3	17.8	18.3	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.3	22.8	23.3
715	17.4	17.9	18.4	18.9	19.4	19.9	20.4	20.9	21.4	21.9	22.4	22.9	23.4
720	17.6	18.1	18.6	19.1	19.6	20.1	20.6	21.1	21.6	22.1	22.6	23.1	23.6
725	17.8	18.3	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.3	22.8	23.3	23.8
730	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0
735	18.1	18.6	19.1	19.6	20.1	20.6	21.1	21.6	22.1	22.6	23.1	23.6	24.1
740	18.3	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.3	22.8	23.3	23.8	24.3
745	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5
750	18.7	19.2	19.7	20.2	20.7	21.2	21.7	22.2	22.7	23.2	23.7	24.2	24.7
755	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.3	22.8	23.3	23.8	24.3	24.8
760	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0
765	19.2	19.7	20.2	20.7	21.2	21.7	22.2	22.7	23.2	23.7	24.2	24.7	25.2
770	19.4	19.9	20.4	20.9	21.4	21.9	22.4	22.9	23.4	23.9	24.4	24.9	25.4
775	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5
780	19.7	20.2	20.7	21.2	21.7	22.2	22.7	23.2	23.7	24.2	24.7	25.2	25.7
785	19.9	20.4	20.9	21.4	21.9	22.4	22.9	23.4	23.9	24.4	24.9	25.4	25.9

Spontaneous Ignition Temperatures in Oxygen and Air (Moore).

Description.	Specific gravity.	Temperature of spont. ignition. In oxygen.	In air.
		°C.	°C.
Crude petroleum and residua :			
Crude petroleum (Texas)	0·936	268·5	416
Crude petroleum (California)	0·961	262	420
Crude petroleum (Mexico)	0·949	258	425
Crude petroleum (Borneo)	0·939	269	380
Anglo-Persian Oil Co.'s oil ..	0·894	254	408
Petroleum distillates :			
Petrol	0·718	279	361
Petrolite kerosene	0·814	251·5	432
Taxibus motor spirit	0·729	272	390
Pratt's Perfection spirit, No. 1 ..	0·710	272	383
Pratt's Perfection spirit, No. 2 ..	0·724	270	371
Shale oil :			
Lighthouse oil	0·803	251	322
Oil engine oil	0·768	253	333
Oil gas tar distillates :			
"Special distillate" of O.G. tar ..	0·995	429	—
Oil gas tar creosote	1·036	473	—
Oil gas tar :			
Water gas tar	1·080	445	—
Carburetted water gas tar	1·053	445	—
Carburetted water gas tar ..	1·078	437	—
Water gas tar	1·074	464	—
Raw tars :			
Horizontal retort tar	1·114	445	—
Horizontal retort tar	1·123	454	—
Blast furnace tar	1·172	498	—
Tar from low temp. carbonisation ..	0·987	307	508
Vertical retort tar	1·102	474	—
Coke oven tar (Simon-Carvé ovens)	1·132	494	—
Coke oven tar (Hopper ovens) ..	1·145	495	—
Coke oven tar (Coppée ovens) ..	1·140	488	—
Tar distillates :			
Benzol 100's	0·875	566	—
Toluol 90's	0·863	516	—
Xylol (commercial)	0·860	484	—
Premier Tarless Retort tar oil ..	0·992	349	—
Paris gas works coal tar oil . .	1·080	449	—
Coke oven tar oil	1·046	478	—
Creosote oil	1·010	415	—
Blast furnace creosote oil	0·988	463	—
Miscellaneous :			
Alcohol	0·817	395	518
Asphaltum from petroleum oil ..		260	
Naphthalene			

Limits of Inflammability of Gas Mixtures with Air.

Combustible gases or vapours in admixture with air will only propagate flame if there is sufficient, but not too much, combustible gas present in the mixture. The "lower limit" represents the least percentage, by volume, of inflammable gas, the "upper limit" the greatest percentage of inflammable gas, in mixtures which will propagate flame.

Lower limits for downward propagation of flame in a tube (Le Chatelier and Boudouard, *Compt. rend.*, 1898, **126**, 1510, *et seq.*):—

Hydrogen	10.0 per cent.		Turpentine	0.73 per cent.
Carbon monoxide	16.0 ,,		Acetone	2.9 ,,
Carbon disulphide	1.94 ,,		Methyl alcohol	6.0 ,,
Illuminating gas	8.1 ,,		Ethyl alcohol	3.07 ,,
Methane	6.0 ,,		n-Propyl alcohol	2.55 ,,
Pentane	1.1 ,,		i-Propyl alcohol	2.65 ,,
Hexane	1.3 ,,		i-Butyl alcohol	1.68 ,,
Heptane	1.1 ,,		Allyl alcohol	3.04 ,,
Octane	1.0 ,,		Amyl alcohol	1.19 ,,
Nonane	0.83 ,,		Acetic acid	4.05 ,,
Acetylene	2.8 ,,		Ether	1.9 ,,
Amylene	1.6 ,,		Ethyl acetate	2.3 ,,
Benzene	1.5 ,,		Ethyl nitrate	3.8 ,,
Toluene	1.3 ,,			

Limits for downward propagation of flame in a Bunte burette (Eitner):—

	Lower limit.		Upper limit.	
Hydrogen	9.45 per cent.		66.4 per cent.	
Carbon monoxide	16.5 ,,		74.95 ,,	
Water gas ($CO + H_2$)	12.4 ,,		66.8 ,,	
Methane	6.1 ,,		12.8 ,,	
Ethylene	4.1 ,,		14.6 ,,	
*Coal gas	7·9 ,,		19.1 ,,	
Acetylene	3.45 ,,		52.2 ,,	
			(75 per cent. in large vessel)	
Alcohol	3.95 ,,		13.65 per cent.	
Ether	2.75 ,,		7.7 ,,	
Benzene	2.65 ,,		6.5 ,,	
Pentane	2.4 ,,		4.9 ,,	
Benzine	2.4 ,,		4.9 ,,	

* Hydrogen, 50.7 per cent.; methane, 34.3 per cent.; carbon monoxide, 7.1 per cent.; heavy hydrocarbons, 4.3 per cent.; carbon dioxide, 2.0 per cent.; nitrogen, 1.6 per cent.

Lower limits of inflammability for complete combustion of the mixture in a 2-litre globe (Burgess and Wheeler, *Journ. Chem. Soc.*, 1911, **99**, 2013):—

Methane	5.6 per cent.		n-Butane	1.65 per cent.
Ethane	3.1 ,,		n-Pentane	1.37 ,,
Propane	2.2 ,,		i-Pentane	1.32 ,,

Lower limits for indefinite continued propagation of flame upwards, but not downwards (Coward and Brinsley, *Journ. Chem. Soc.*, 1914, **105**, 1859):—

Hydrogen 4.1 per cent.;   Methane 5 3 per cent.;
Carbon monoxide 12.5 per cent.

Composition, Calorific Value, etc., of Gaseous Fuels.
(Brame).

Description.	Percentage Composition.					B. Th. U. Per C. Ft.		Air for Combustion.	
	H_2,	CH_4	C_nH_{2n}	CO	Non-combustibles.	Gross.	Net.	Theory.	Practice.
Coal and Coke Oven Gas .. .. : .. :	50	33	3	8	6	630	550	4.7	8.0
Blue Water Gas .. .. : .. :	48	–	–	44	8	315	290	2.2	4.0 (?)
Producer Gas with ammonia recovery	25	2	0.5	12.5	60	150	145	1.1	1.25
Producer Gas Non-Recovery .. :	12	3	0.5	24.5	60	170	160	1.2	1.25
Producer Gas Coke or Anthracite ..	16	–	–	25	59	140	130	0.9	1.25
Air Producer Gas from Coke .. : :	1	–	–	29	70	105	105	0.75	1.0
Blast Furnace Gas .. .. : .. :	1	–	–	26.5	72.5	97	97	0.65	1.0

Typical Analyses of By-Product Coke Oven Gas.
(Babcock and Wilcox Co.)

CO_2	O	CO	CH_4	H	N	Gross B.Th.U. per Cubic foot.
0.75	Trace	6.0	28.15	53.0	12.1	505
2.00	Trace	3.2	18.80	57.2	18.0	399
3.20	0.4	6.3	29.60	41.6	16.1	551
0.80	1.6	4.9	28.40	54.2	10.1	460

Typical Analyses of Blast Furnace Gas.
(Babcock and Wilcox.)

	CO_2	O	CO	H	CH_4	N
Bessemer Furnace	9.85	0.36	32.73	3.14	—	53.92
Bessemer Furnace	11.4	—	27.7	1.9	0.3	58.7
Bessemer Furnace	10.0	—	26.2	3.1	0.2	60.5
Bessemer Furnace	9.1	—	28.7	2.7	0.2	59.3
Bessemer Furnace	13.5	—	25.2	1.43	—	59.87
Bessemer Furnace	10.9	—	27.8	2.8	0.2	58.3
Ferro Manganese Furnace	7.1	—	30.1	—	—	62.8†
Basic Ore Furnace	16.0	0.2	23.6	—	—	60.2†

Average of 20 samples.   † Includes H and CH_4.

Typical Analyses (by volume) and Calorific Values of Natural Gas.
(Babcock and Wilcox Co.)

Locality of Well	H	CH₄	CO	CO₂	N	O	Heavy Hydro-carbons.	H₂S	B.th.u. per Cubic Foot Calculated.*
Anderson, Ind.	1.86	93.07	0.73	0.26	3.02	0.42	0.47	0.15	1017
Marion, Ind.	1.20	93.16	0.60	0.30	3.43	0.55	0.15	0.20	1009
Muncie, Ind.	2.35	92.67	0.45	0.25	3.53	0.35	0.25	0.15	1004
Olean, N.Y.	—	96.50	0.50	—	—	2.00	1.00	—	1018
Findlay, O.	1.64	93.35	0.41	0.25	3.41	0.39	0.35	0.20	1011
St. Ive, Pa.	6.10	75.54	Trace	0.34	—	—	18.12	—	1117
Cherry Tree, Pa.	22.50	60.27	Trace	2.28	7.32	0.83	6.80	—	842
Grapeville, Pa.	24.56	14.93	Trace	Trace	18.69	1.22	40.60	—	925
Harvey Well, Butler Co.,	13.50	80.00	Trace	0.66	—	—	5.72	—	998
Pittsburgh, Pa.	9.64	57.85	1.00	0.80	23.41	2.10	6.00	—	748
Pittsburgh, Pa.	20.02	72.18	1.00	—	—	1.10	4.30	—	917
Pittsburgh, Pa.	26.16	65.25	0.80	0.60	—	0.80	6.30	—	899

* B.th.u approximate.

Ignition Temperatures of Gaseous Mixtures in °C at Ordinary Pressures.
(Dixon and Coward).

Gas.	In Oxygen.	In Air.
Hydrogen	580 – 590	580 – 590
Carbon monoxide	637 – 658	644 – 658
Methane	556 – 700	650 – 750
Ethane	520 – 630	520 – 630
Ethylene	500 – 519	542 – 547
Acetylene	400 – 440	406 – 440

LUBRICANTS.

H. Moore, M.Sc.Tech.

The main sources of lubricating oils are :—

1. *Vegetable Oils.* The oils of this class most commonly employed in lubrication are castor oil, rape oil and cocoanut oil.

2. *Animal Oils.* Such as lard oil, tallow oil, neatsfoot oil and sperm oil.

3. *Derivatives of Petroleum.* These vary greatly in character and their physical properties may be adjusted by alteration of the temperature limits of the fractions collected during the distillation and of the residues. By far the greatest bulk of lubricating oil used at the present time is of petroleum origin.

4. *Shale Oil.* Certain of the distillates from shale oil are used as lighter grades of lubricating oil. Their use is limited to the United Kingdom, where the products of the Scottish shale oil industry are employed. These oils are generally of the spindle oil variety.

5. *Coal Tar Derivatives.* In countries where petroleum products are very high in price, coal tar products have been employed for lubricating purposes. The main fraction employed is Anthracene Oil, the heaviest grade of coal tar distillate, which is sometimes used direct, but more often as a base for grease manufacture. It is generally considered inferior to the petroleum products.

6. *Lignite Tar Oil.* The lignite tar products are mainly unsaturated hydrocarbons together with cresols and a small quantity of nitrogen compounds. They may, therefore, be considered as products intermediate chemically between the petroleum derivatives and the coal tar products. The crude distillates contain paraffin wax. Lubricants prepared from lignite distillates are generally considered as cheap substitutes for the petroleum products, and are only employed in any quantity in the vicinity of the Saxon lignite fields, where economic conditions favour their use.

The great bulk of lubricants used in commerce consists of petroleum products or of a blend of petroleum products with animal or vegetable oils. Shale oils are very similar to the corresponding petroleum products, and coal tar and lignite oils are seldom used except in the lowest classes of greases and gear oils.

Bearing this in mind, lubricants may be classified as fatty oils, mineral oils and compounded oils, the latter being a mixture of a small quantity of saponifiable oil with a large quantity of petroleum oil. Further than this, the petroleum oils may be divided into two classes : (1) Straight petroleum products, and (2) Blended oils. The first consists of a petro-

leum fraction or residue as it leaves the refinery, whilst the second consists of oils which have been prepared by the blending of two or more refinery products.

Animal and Vegetable Oils.

These oils in the past have been of great importance as lubricants, but during recent years have been rapidly supplanted by the cheaper, and in some cases, more efficient, mineral oils, or compounded oils. There are, however, several purposes for which saponifiable oils are still employed, for instance, castor oil for racing automobile engines and aircraft rotary engines. Pure saponifiable or heavily compounded oils are also occasionally employed in the textile trade as "Stainless loom oils," as they may be removed easily from the fabric in case it becomes splashed with the lubricant. There are numerous other minor purposes for which uncompounded saponifiable oils are used as lubricants.

Mineral Oils.

The mineral oils, of which the petroleum oils form the only important class, are obtained during the distilliation of crude petroleum, when the heavier fractions or residues are refined by means of sulphuric acid washes, alkali washes, colour filtration and wax removal processes. In some cases the distillate is treated by acid and alkali washes and the colour filtration omitted; sometimes colour filtration is employed, and the acid and alkali washes left out. Colour filtration may be carried out by percolating the oil through bauxite or fuller's earth, or by heating it in the presence of these substances. Recently the use of special clays, mainly originating in California, has come into vogue. In this case, the oil is heated together with the finely divided clay and afterwards passed through a filter press for removal of the clay. The wax extraction process involves cooling and filtering the oil, or mixing with a light solvent, cooling and filtering. Another method necessitates mixing the oil with a light solvent (usually petroleum naphtha) and then centrifuging, when the wax is continuously discharged from the centrifuge, whilst the mixture of solvent and oil is removed from the outlet and afterwards treated for recovery of the solvent, leaving a viscous, wax-free oil.

From these processes a large range of distillates is obtained; the lighter fractions are very thin spindle oils slightly heavier than mineral colza or burning oil, whilst the heavier fractions are viscous red or pale oils. The nature of these products, and the physical tests carried out on them, depend very much on the crude base employed. As a general rule, oils of Pennsylvanian origin are of low viscosity relative to their boiling point, and possess high flash points and low specific

gravities. Oils of Californian or Texas origin, being comparatively rich in unsaturated bodies and naphthenes, are more viscous, lower in flash point and higher in specific gravity. The Pennsylvanian oils consist largely of saturated aliphatic hydrocarbons. Russian oils, which are of almost pure naphthene base, possess physical characteristics somewhat similar to those of the Californian and Texas oils. The paraffin base oils generally require treatment for the removal of wax during the refining process, as oils of this base are rich in wax. Californian and Texas oils are usually free from wax, although some wax-containing oils rich in saturated aliphatic bodies occur in both Texas and California. Also, there are occurrences of pure aliphatic oils in the Russian fields. Oils from Persia, Burma and the East Indies generally contain a considerable proportion of aromatic hydrocarbons. The oils of Pennsylvanian origin are considered to be of the greatest value on account of their high flash point, and also because of their property of maintaining viscosity at higher temperatures. As there is a practical limit to the viscosity of distillates, and as oils are frequently required possessing a higher viscosity than that of the distillates, it is usual to manufacture more viscous oils by blending a distillate with a residue. The residual oil used for these blends is usually filtered through decolourising material, in order to reduce the bitumen content and give a finished product of a green instead of a black appearance. The dark residue from the still is used direct for steam engine cylinder lubrication and is generally known as Dark Cylinder Oil, whilst the decolourised product prepared from the Dark Cylinder Oil is usually known as Filtered Cylinder Oil. The latter is reblended in various proportions with distillates, and gives viscous lubricating oils such as those usually used for motor lubrication purposes.

Blended Oils.

Experience has shown that for some purposes a mineral oil to which a small amount of saponifiable oil has been added gives better lubrication in practice than the pure mineral oil. Scientific investigation has indicated that this is a surface tension phenomenon, and that the presence of a small quantity of saponifiable oil gives the resulting product the property of maintaining a film between two surfaces under very high pressure. Mineral oil possesses this property, but not to the same extent as a compounded product, and on this account some of the better class motor oils and also steam cylinder oils contain from $2\frac{1}{2}$ to 10 per cent. of saponifiable oil. Another type of compounded oil which is largely used for marine engine lubrication is one consisting of mineral oil compounded with oxidised saponifiable oil to the extent of

10 to 30 per cent. These oxidised saponifiable oils, such as blown rape, blown cottonseed and blown whale oils, possess very high viscosities and give a high viscosity to blends containing them. In addition to this, products containing blown oils readily emulsify with water, a property which is necessary for certain purposes, particularly for marine engine oils.

Testing of Lubricating Oils.

A large number of tests is employed in the valuation of lubricating oils, the majority of them being only employed on oils for special purposes, whilst a few of them are of general application. In practically all cases lubricating oils are tested for specific gravity, flash point, and viscosity.

The specific gravity may be determined by any of the common methods, usually by the specific gravity bottle, hydrometer or by Mohr's balance. The results are not of direct importance, but are of the greatest value in indicating the nature of the base hydrocarbons a mineral oil or a slightly compounded oil.

The flash point may be determined by any of the closed or open methods, and in some cases both open and closed tests are made. The refineries rely largely on the open flash point, but in many cases consumers use the closed flash point. For specification purposes the Pensky-Martin Closed Flash Tester is the usual instrument used, as it is accepted as standard throughout the United States, British Possessions, Germany and the majority of the European countries.

Regarding viscosity, several instruments are used, and in addition to this the temperature at which viscosities are determined vary in different countries. In the United States the Saybolt instrument is employed, and the most usual temperatures at which the viscosity is determined are 100° F. and 212° F., additional temperatures being sometimes employed. In British practice the Redwood instrument is used, the temperatures being 70° F., 100° F., 140° F., and 200° F. Throughout the European countries the Engler instrument is employed, although in France the Barbet instrument is sometimes used. The temperatures at which Engler determinations are usually made are 20° C., 50° C., and 100° C. It is possible to convert with a fair amount of accuracy from one viscosity reading to another if both readings are made at the same temperature, but it is difficult to obtain even a rough estimate of the viscosity at one temperature from a viscosity at another temperature. Conversion tables for Saybolt, Engler and Redwood readings are given in adjoining table.

Conversion Table for Redwood, Saybolt, and Engler Viscosimeters.

U.S. Bureau of Standards, Bulletin No. 112.

Time, Engler	Time, ratio			Time, Redwood	Time, Engler	Time, ratio			Time, Redwood
	Engler-Saybolt	Engler-Redwood	Saybolt-Redwood*			Engler-Saybolt	Engler-Redwood	Saybolt-Redwood	
Sec.				Sec.	Sec.				Sec.
56	1.73	2.61	1.51	21.5	140	1.55	1.81	1.17	77.5
58	1.72	1.93	1.12	30.0	150	1.54	1.80	1.17	83.2
60	1.71	1.93	1.13	31.2	160	1.53	1.80	1.17	89.1
62	1.70	1.92	1.13	32.2	180	1.53	1.80	1.17	100.3
64	1.69	1.91	1.13	33.4	200	1.52	1.79	1.18	111.9
66	1.68	1.91	1.13	34.6	225	1.52	1.79	1.18	126.0
68	1.68	1.90	1.14	35.8	250	1.51	1.78	1.18	140.3
70	1.67	1.90	1.14	36.9	275	1.51	1.78	1.18	154.4
75	1.65	1.88	1.14	39.8	300	1.51	1.78	1.18	168.5
80	1.63	1.87	1.15	42.7	325	1.51	1.78	1.18	183.0
85	1.62	1.86	1.15	45.7	350	1.50	1.78	1.18	197.0
90	1.61	1.86	1.15	48.5	375	1.50	1.77	1.18	211.3
95	1.60	1.85	1.16	51.4	400	1.50	1.77	1.18	225.5
100	1.59	1.84	1.16	54.3	500	1.50	1.77	1.18	282.0
110	1.58	1.83	1.16	60.1	600	1.50	1.77	1.18	339.0
120	1.56	1.82	1.16	66.0					
130	15.6	1.81	1.17	71.7					

* These values were calculated directly from the times of discharge and differ in some cases by 0.01 from values calculated from the two previous columns.

In order to discover whether an oil is blended, the most satisfactory method is to determine the saponification value. In practice this method is much more satisfactory than making an extraction of the compounded oil, but the result is not directly calculable to percentage unless the saponification value of the saponifiable oil present in the blend is already known. It is, however, usual to assume a saponification value of 180 for unknown fatty oils in calculating the percentage of saponifiable matter. This method is quite satisfactory and sufficiently accurate providing the quantity of saponifiable matter is below 10 per cent., but where oils are very heavily compounded, it is preferable to saponify and extract.

Oils required for internal combustion engines are frequently tested for the Conradson Coke Value as a method of measuring the tendency to carbonise in the cylinders.

Turbine oils and oils for the lubrication of high-speed steam engines are required to possess the property of separating readily from water after a mixture of the oil and water has been violently agitated. On this account they are tested for demulsification value either by the Conradson or Herschel method. The results of these tests are of the greatest importance in the valuation of this class of oil.

Transformer and Switch oils, which are not, strictly speaking, lubricating oils, but are a special class of mineral spindle oils used for electric insulation, are the subject of special tests, the most important of which are the Sludge value, Evaporation test, and the Dielectric Strength test, these being employed in addition to the commoner tests.

The British methods of testing petroleum products are published by the Institution of Petroleum Technologists ("Report of the Standard Methods of Testing Petroleum and its Products"); the United States methods are officially given in the Bureau of Mines Technical Paper 323.

ANALYSIS OF CLAYS, FIREBRICKS, AND SILICA MATERIALS.

J. W. MELLOR, D.Sc.

Determination of hygroscopic moisture.

About 5 grm. of the finely-ground clay are dried in a toluene oven or air-bath at 110° until there is no further loss in weight; about 4 hrs. is usually sufficient.

Determination of loss on ignition.

About 1 grm. of the dry clay is heated in a platinum crucible, first over a small flame, then over a Méker or Téclu burner, and finally over a blowpipe flame for about 20 mins. The crucible is allowed to cool and weighed. The crucible and contents are again heated over the blowpipe flame for 5 mins., cooled, and weighed. Low results are usually due to the incomplete combustion of the carbon; high results may be due to losses by spurting produced by heating too rapidly.

Determination of silica.

The ignited clay in the platinum crucible is intimately mixed with 10–15 grm. of sodium carbonate. The mixture is gently heated over a Méker or Téclu burner, and finally fused at a bright red heat for 30 mins. or until the contents of the crucible are in a state of quiet fusion. The red-hot crucible is dipped in water to about two-thirds of its depth in order to solidify the contents rapidly. The cake is extracted with as small an amount of water as possible, and the washings collected in a 250 cc. basin; the cake will probably be detached from the crucible by this treatment, and is transferred to the basin. The basin is almost covered with a clock-glass, and 30 to 35 cc. of concentrated hydrochloric acid are run into the basin; the covered basin is kept warm on a water-bath until all action has subsided and the cake has disintegrated; any large pieces which remain are crushed to powder with a small agate pestle. The platinum crucible and lid are rinsed into the basin by means of hydrochloric acid and hot water. The solution is evaporated to dryness, and the contents heated in an air-oven at 110° until dry. The mass is moistened with concentrated hydrochloric acid, 60–70 cc. of hot water added, and the liquid filtered; the precipitate is washed with hot water until free from chlorides. The filtrate is returned to the basin, evaporated to dryness, and the mass is heated as before until it is free from hydrochloric acid. The residue is again digested with hydrochloric acid and about 60–70 cc. of hot water, filtered, and the residue washed with hot water until free from chlorides.

The two filter-papers are transferred to a weighed platinum

crucible, and charred slowly without flame. The carbon is burnt off slowly, and the crucible and its contents heated over the blowpipe for 15 mins. with the lid off, and then 5 mins. with the lid in position. The result is entered as " uncorrected weight of crucible and silica." The silica contains small quantities of the oxides of titanium, phosphorus, aluminium, and iron. 5 cc. of water are added to the crucible and a few drops of concentrated sulphuric acid in order to prevent, later, the volatilisation of titanic fluoride. About 15 cc. of hydrofluoric acid are carefully added a few drops at a time. The solution is cautiously evaporated to dryness on a sand-bath. The outside of the crucible is freed from sand, the crucible ignited over a burner for 5 mins., and when cool, weighed. The result is entered as " weight of crucible + residue." Later the alumina is ignited in the same crucible together with the silica residue.

The ammonia precipitate.

From 2 to 3 grm. of solid ammonium chloride and an excess of ammonia are added to the hot filtrate from the silica, and the solution filtered immediately. The precipitate is washed immediately two or three times with hot water, a hole made in the filter paper, and the precipitate washed back into the beaker from which it has just been filtered. The precipitate is redissolved in a slight excess of hydrochloric acid, and the filter paper is washed very thoroughly with hot water and kept for ignition later. The combined filtrates are heated to the boil, an excess of ammonia solution is added, the liquid filtered into the beaker previously used, and the precipitate washed free from chlorides by means of a slightly alkaline solution of ammonium nitrate (made by mixing 5 cc. of concentrated nitric acid with water, adding ammonia until alkaline, and making the solution up to a litre). The combined filtrates are evaporated to about 100 cc., and, whilst still hot, 2 to 3 cc. of ammonia are added. The liquid is filtered, and the precipitate washed free from chlorides with hot ammonium nitrate solution, care being taken that the alumina precipitate does not at any time become dry. The filtrate is reserved for the determination of lime and magnesia.

The three filter papers containing the " alumina " precipitate are dried in the platinum crucible containing the silica residue ; the crucible is heated very slowly until the paper is charred, and the temperature raised until all the carbon is burnt off, finally heating for 15 mins. over a Meker burner. After weighing, the ammonia precipitate is very slowly dissolved by fusing with 5 to 6 grm. of fused potassium bi- or pyro-sulphate. The cold cake is transferred to a basin with

about 150 cc. of water, and 10 cc. of concentrated sulphuric acid are added. The mixture is heated on a water-bath until dissolved and made up to 250 cc. This solution is retained for determination of the iron and titanium.

NOTES.—(a) If the clay contains manganese, 2 or 3 cc. of bromine water are added to the solution before the ammonia precipitation, and the liquid filtered as usual. In the second precipitation 1 or 2 cc. of bromine water are again added, and the procedure is then as above described. The ammonia precipitate is washed thoroughly.

(b) In the case of a silica brick (containing over 92% of silica), where the ammonia precipitate is below 5%, only a slight excess of ammonia is added to the washings from the silica, and the excess is boiled off. The liquid is filtered, and the precipitate washed with ammonium nitrate solution as rapidly as possible.

Determination of ferric oxide.

A colorimetric process is used for materials which ignite to a white and buff colour; the ordinary permanganate process for those which give deeper colours. The colour of the sample in the crucible after it has been heated for "loss on ignition" is a good criterion to determine which process is the better. A suitable amount of the solution obtained by fusing the ammonia precipitate with pyrosulphate, etc., is made up to 250 cc. About 25 cc. are sufficient for a normal clay containing about 0·5% of ferric oxide. 5 cc. of standard iron solution (see below) is made up to 100 cc. with distilled water. The latter solution is transferred to a burette reading to 0·05 cc., and another burette is filled with distilled water. Two similar glasses are now required—the test glasses of a colorimeter can be used. Specimen glasses with parallel sides—about 3 cm. square and 8 cm. high—serve excellently. A mixture of 10 cc. of the solution to be tested with 10 cc. of potassium thiocyanate solution is made in one test glass, and in the other a mixture of 10 cc. of a solution of potash alum with 10 cc. of thiocyanate solution. The tints are viewed by light transmitted through the parallel sides of the glasses. The standard iron solution is added to the test glass with the potash alum solution and an equivalent amount of distilled water to the other, stirring thoroughly after each addition. When the tints of the liquids in the two test glasses are the same, the amount of iron oxide in the sample can be computed.

For material containing larger amounts of iron, the pyrosulphate fusion is made up to 150 cc., and 20 cc. of

concentrated sulphuric acid employed. The solution is reduced with purified zinc (about 10 grm.) until a drop sample gives no reddish-brown coloration with potassium thiocyanate. The reduced solution is made up to 250 cc., and titrated with standard potassium permanganate in the usual manner.

Standard iron solution. 0·6303 grm. of ferric potassium alum are dissolved in water, 5 cc. of concentrated sulphuric acid added, and the solution made up to 1 litre. **1 cc. = 0·0001 grm. of Fe_2O_3.**

Potassium thiocyanate solution. 97 grm. of potassium thiocyanate per litre.

Potash alum solution. 0·05 grm. of alumina (free from iron) are fused with 5 grm. of potassium pyrosulphate, the cold cake extracted with water, 10 cc. of concentrated sulphuric acid added, and the solution made up to 1 litre.

Determination of titanium.

For the colorimetric determination of titanium, similar test glasses to those employed for the iron determination are used. 50 cc. of the solution of the cake from the pyrosulphate fusion are mixed with 7 to 8 cc. of hydrogen peroxide (free from fluorides), and the solution made up to 100 cc. 5 cc. of " standard titanium solution " are mixed with 5 cc. of hydrogen peroxide, and the solution made up to 100 cc. One of the test glasses is about half-filled with the solution to be tested. 10 cc. of the diluted standard titanium solution is pipetted into the other glass, and water added from a burette until the tints of the liquids in both test glasses are similar. The tints are viewed by light transmitted through the parallel sides of the test glasses. The necessary data for calculating the amount of titanium in the given sample are now available.

The weights of ferric oxide and titanic oxide in the ammonia precipitate have now been determined, and if these are subtracted from the total weight of this precipitate the difference will represent the weight of the alumina in the given sample.

Standard titanium solution. 1 grm. of pure titanic oxide is fused with 10 grm. potassium pyrosulphate, the cold cake extracted with cold water, and 10 cc. of concentrated sulphuric acid added. After dissolving at as low a temperature as possible, the solution is made up to 1 litre. **1 cc. = 0·001 grm of TiO_2.**

Determination of lime.

The filtrate from the ammonia precipitate is boiled with 1–3 grm. of ammonium oxalate, and 5–10 cc. of concentrated ammonia solution are added. The solution is agitated and allowed to stand on the water-bath for 2 hrs. The liquid is

filtered, the precipitate washed once, a hole made in the filter paper, and the precipitate washed into the beaker from which it has been filtered; the precipitate is redissolved in nitric acid, and ammonium oxalate and ammonia are added to the boiling solution as before. The liquid is allowed to stand 2 or 3 hrs., filtered, and the precipitate washed free from chlorides with hot water. The dry precipitate is ignited in a weighed platinum crucible. The ignition is conducted slowly at first, and finally over a blast for about 15 mins.—placing the lid on the crucible for the last 5 mins. The crucible is weighed rapidly when cool.

Determination of magnesia.

1 to 2 grm. of sodium ammonium phosphate are added to the first filtrate from the ammonium oxalate precipitate, and the mixture boiled whilst covered with a clock-glass. 10 cc. of concentrated ammonia are added, and the mixture allowed to stand for at least 3 hrs. The mixture is stirred vigorously when cold, filtered, and the precipitate washed once with cold water, rejecting the filtrate. A hole is made in the filter-paper, the precipitate washed into the beaker from which it has been filtered, and the ammonium magnesium phosphate redissolved in nitric acid. The solution is heated to boiling, 1–2 grm. of sodium ammonium phosphate and 10–15 cc. of concentrated ammonia are added, and the mixture allowed to stand for 2 hrs. The cold mixture is thoroughly stirred, filtered through a weighed Gooch crucible, and the precipitate washed free from soluble phosphates with cold ammonia solution (1 : 8). The dry precipitate is ignited, cooled, and weighed as magnesium pyrophosphate.

Determination of alkalies.

About 0·5 grm. of finely powdered dry clay are intimately mixed with about 0·5 grm. of ammonium chloride and 3 grm. of calcium carbonate in an agate mortar, and transferred to a platinum crucible, cleaning out the mortar with a further gram of calcium carbonate. The crucible and contents are heated over a small Bunsen flame for about 15 mins. The lid is kept partly on the crucible whilst the ammonium chloride is being volatilised, then placed in position, and the crucible and contents heated for 1 hr. with the lower third of the crucible at a dull red heat (not sufficiently high to melt the mass). The crucible is allowed to cool slowly, the cake is transferred to a porcelain dish, and the crucible is thoroughly washed with hot distilled water. After standing 2 or 3 mins., the cake in the dish is gently crushed to powder with an agate pestle. The mass is digested with 80 cc. of water for 30 mins., filtered, and the precipitate washed with hot

water 8 or 9 times; the filtrate should occupy 100—150 cc. The precipitate is rejected. 10 cc. of ammonium carbonate (see later) are added to precipitate the lime from the boiling hot filtrate; the liquid is filtered and the filtrate retained. The precipitate is washed into the same beaker from which it was filtered, and dissolved in hydrochloric acid (about 5 cc.). The solution is boiled and a slight excess of ammonia and ammonium carbonate added, and the mixture is filtered into the same beaker as before. The solution is evaporated to dryness in a platinum basin, and the dry residue ignited by gradually raising the temperature to faint redness in order to volatilise the ammonium salts. 3 cc. of ammonium carbonate are added to the residue in order to precipitate the last traces of lime, the liquid covered with a clock-glass, and allowed to stand over-night. The mixture is filtered into a small platinum dish; the precipitate is washed with a solution of ammonium carbonate, and the filtrate is again evaporated to dryness on a water-bath. As the liquid tends to spurt during the early stages of the evaporation, the basin is covered with a clock-glass and any liquid adhering to the glass is washed back into the basin. When dry the contents of the dish are moistened with a small amount of concentrated hydrochloric acid and again evaporated. The residue is ignited at a dull red heat, cooled, and weighed. The platinum dish is re-heated and weighed. The difference in weight represents the alkali chlorides. The residue containing the alkali chlorides is washed with hot water into a small porcelain dish, and evaporated almost to dryness with perchloric acid, 10 cc. of water added, and again evaporated almost to dryness. Six times the weight of the mixed chlorides represents the number of cc. of 30% perchloric acid of Sp. Gr. 1·20 to be used in the test. The residue is treated with a mixture of 97 volumes of absolute alcohol, 3 volumes of water, and 0·25 volumes of perchloric acid. The mixture is filtered at once through a weighed Gooch crucible previously heated to 120°, and the residue washed with the alcohol mixture indicated above. The crucible and contents are then dried at 120° for about 45 mins., and weighed. The potassium perchlorate weighed is calculated to potassium chloride, which is subtracted from the weight of the mixed chlorides to obtain sodium chloride; the corresponding potash and soda contents are then calculated.

NOTES.—(a) The volume of the liquid should be kept as low as possible.

(b) The first precipitate should be well washed, particularly if the amount of alkali is large.

(c) The first ignition must not be above 700°, and subsequent ignitions should not exceed a faint red heat, or alkalies will be lost by volatilisation.

(d) The last washing should be made with ammonium carbonate solution, or the result will be too high.

(e) Only porcelain or platinum, not glass, vessels should be used for the evaporation

Ammonium carbonate solution.

100 grm. of ammonium carbonate are dissolved in 100 cc. of concentrated ammonia (0·880), and the solution made up to 500 cc. with water.

POROSITY TEST.

The porosity of a brick is to some extent a measure of the " density " and texture of the brick. The test is conducted as follows :—A representative piece of the firebrick or refractory material to be tested is cut into rough cubes, about 2 in. side. The sample is dried at 110° for about 2 hrs. and weighed. It is then soaked in water under reduced pressure for some hours, preferably overnight—a vacuum dessicator is very suitable for this purpose. The piece is then weighed while suspended in water as in ordinary specific gravity determinations ; the surface water is wiped off, and the piece is again weighed. The porosity, or the volume of the pores expressed as a percentage volume of the whole piece, is 100 times the quotient obtained by dividing the difference between weights of the piece soaked and dried by the apparent loss in weight which the soaked piece suffers when weighed in air and then weighed suspended in water. Duplicates should agree within 0·2%. With very dense or close textured material, it is necessary to soak the sample for 2 or 3 days, otherwise the air bubbles in the centre of the piece are not displaced by water. The elimination of the air is also assisted by reducing the pressure inside the dessicator. The specific gravity of the sample may also be calculated from the above data, since the apparent specific gravity of the lump is the quotient obtained by dividing the weight of the dry sample by the apparent loss in weight which the soaked piece suffers when weighed in air and then suspended in water. The specific gravity of the solid material (powder) is the quotient obtained by dividing the weight of the dry test piece by the apparent loss of weight which the dry piece suffers when weighed in air and then suspended in water—after soaking.

The apparent specific gravity of an average firebrick in lump

usually varies from 1·5 to 1·9, and the powdered brick has a specific gravity ranging between 2·3–2·6; the porosity varies from 20 to 35%.

DETERMINATION OF THE REFRACTORINESS OF FIREBRICKS, FIRECLAYS, Etc.

A representative piece of the material is chipped or shaped into the form of a cone about $1\frac{1}{2}$ inch in height. The cone is cemented to the centre of a refractory disc, about 2 inches in diameter, by means of a mixture of ground bauxite and fireclay, and Seger cones are cemented around the test-piece. The cones are chosen in the order of increasing temperatures according to the material being tested. The cones should be sloped slightly in the outward direction, so that they will not fall on to the test-piece when they melt. The disc is placed on the supports of the lifting-table of a Hirsch or similar electric furnace. The current is started running with a power of 2 or 3 kilowatts. The temperature of the furnace must be increased regularly about 50° per 5 mins., until the cone begins to melt. If the increase in temperature is too rapid the voltage must be decreased by means of an adjustable transformer or resistance. The power taken at high temperature varies from 7–10 kilowatts, the voltage has to be varied according as the resistance of the furnace is high or low. The cones should melt at an interval of 5 mins.; if two or more cones squat at nearly the same temperature, the increase in temperature is too rapid, and this makes the softening point of the test-piece appear too high. The temperature at which the test-piece bends over, squats, or shows signs of fusion is taken as the softening point. At this point the current is switched off, the support lowered, and the disc containing test-piece and cones plunged into cold water. This prevents the disc, etc., breaking up on cooling. The softening point of the test-piece is deduced from the cone which bent down last. The squatting temperature of a Seger cone corresponds with the temperature at which the cone bends over so that the tip is level with the base. The selection of the right cones for an unknown sample is made by successive approximation. For example, cones 20, 26, 30, 32 and 35 would be placed on the refractory disc with the clay to be tested. If cones 20 and 26 are down, and 30 to 35 are standing when the clay squats, it would be inferred that the clay squats between cones 26 and 30. In a second trial, therefore, cones 26 to 30 would be placed on the disc with the clay. The softening point of the test-piece often comes between the squatting temperature of the two cones, since the one has gone

down completely and the other one just commenced to bend. The bending temperatures of Seger cones are given in the accompanying table. The comparison of the squatting temperature of refractories with a standard cone is better than expressing the results in terms of a pyrometer reading. The use of the term squatting or softening temperature is also preferable to the term melting point, since refractory materials rarely have a sharp melting point.

APPROXIMATE SQUATTING TEMPERATURES OF SEGER CONES.

Cone No.	°C.	°F.	Cone No.	°C.	°F.	Cone No.	°C.	°F.
022	600	1112	02a	1060	1940	19	1520	2768
021	650	1202	01a	1080	1976	20	1530	2786
020	670	1238	1a	1100	2012	26	1580	2876
019	690	1274	2a	1120	2048	27	1610	2930
018	710	1310	3a	1140	2084	28	1630	2966
017	730	1346	4a	1160	2120	29	1650	3002
016	750	1382	5a	1180	2156	30	1670	3038
015a	790	1454	6a	1200	2192	31	1690	3074
014a	815	1499	7	1230	2246	32	1710	3110
013a	835	1535	8	1250	2282	33	1730	3146
012a	855	1571	9	1280	2336	34	1750	3182
011a	880	1616	10	1300	2372	35	1770	3218
010a	900	1652	11	1320	2408	36	1790	3254
09a	920	1688	12	1350	2462	37	1825	3317
08a	940	1724	13	1380	2516	38	1850	3362
07a	960	1760	14	1410	2570	39	1880	3416
06a	980	1796	15	1435	2615	40	1920	3488
05a	1000	1832	16	1460	2660	41	1960	3560
04a	1020	1868	17	1480	2696	42	2000	3632
03a	1040	1904	18	1500	2732			

DETERMINATION OF THE AFTER-CONTRACTION OR AFTER-EXPANSION OF REFRACTORY MATERIALS.

The so-called test is designed to find the after-contraction or after-expansion of a firebrick, *i.e.* the change in size which the brick is likely to undergo when in use at high temperature. The temperature used for testing refractory material is equivalent to cone 14 (1,410°C.; 2,570°F.). In making the test a rectangular piece of the material—about 3 ins. in length and 1 to 2 ins. in width and depth—is cut from the sample. The opposite ends are ground parallel on an emery or carborundum wheel, and the length measured by means of a vernier gauge.

reading to 0·005 cm. The piece is then fired until the proper cone squats, and is maintained at this temperature for 2 hrs. After the cone has squatted a pyrometer is required to check the fluctuations of temperature. A gas furnace worked with an air-blast is used, with an oxidising atmosphere. When cold the length of the test-piece is again measured and the alteration in size calculated. The test is best done in duplicate, one piece from the outside and one from the inside of the sample. The maximum contraction or expansion allowed by the Gas Engineers' Specification is : *Silica bricks, ·50%* ; *retort material, 1·0%* ; *firebricks, grade I, 0·75%* ; and *firebricks, grade II, 1·15%* .

Additions by Editor.

Standard American Methods.

STANDARD TEST FOR POROSITY AND PERMANENT VOLUME CHANGES IN REFRACTORY MATERIALS.

(American Society for Testing Materials, 1920.)

The sample for this test should consist of at least seven standard-size bricks, and test-pieces are cut from these, so as to remove the original surface of the bricks. The test-pieces should measure $2\frac{1}{2}$ by $2\frac{1}{2}$ by $1\frac{1}{4}$ in., and should be 35 in number, 5 for each of the seven heat treatments. Adhering dust is washed or brushed from the pieces, which are then numbered by means of a refractory stain, dried at 110°C. and weighed to within 0·1 g., giving the dry weight (D). The test-pieces are placed in kerosene of known density (δ) under 24 in. of vacuum for 4 hrs. at 25°C., and allowed to cool to room temperature while immersed. When cool each test-piece is weighed suspended in kerosene at 25°C. to determine its suspended weight (S), and is then wiped with a kerosene-moistened towel, and weighed in air to give the saturated weight (W).

The true specific gravity (T) is obtained by crushing a portion of the dried test-piece to pass through a 120-mesh sieve, and determining the displacement at 25°C. under 24 in.

of vacuum of a 20 grm. sample of the powder in a 50 cc. straight-walled pyknometer under kerosene, correcting for the density of the kerosene.

The required data are given by the following formulæ:

Exterior volume in cc. $(V) = \dfrac{W - S}{\delta}$ - - - - - (1)

Actual volume of open pores in cc. $(V_1) = \dfrac{W - D}{\delta}$ - - (2)

Apparent specific gravity $(T_1) = \dfrac{D}{D - S}\,\delta$ - - - (3)

Volume of sealed pores in cc. $(V_2) = \dfrac{D - S}{\delta} - \dfrac{D}{T}$ - - (4)

The 35 test-pieces are now thoroughly dried at 110°C., placed in a kiln, and heated as rapidly as is consistent with even heat distribution to 1200°C. Five test-pieces are withdrawn, and the kiln temperature raised at the rate of 30° per hour to 1500°C., five test-pieces being withdrawn at each 50° interval from 1200°C to 1500°C. If a sufficient number of brands is under examination to warrant it, separate burns to each temperature are made, and the kiln is sealed and allowed to cool by radiation. If this cannot be carried out, the five test-pieces from each temperature increment should be covered with hot sand immediately on being drawn, or placed in a supplementary kiln and kept at 500°C. until all drawings are completed. This kiln is then sealed and allowed to cool by radiation.

When cold, each test-piece is subjected to the series of tests above, to determine its dry weight, suspended weight, saturated weight, and true specific gravity. From these are calculated the *exterior volume, actual volume of open pores, apparent specific gravity*, and *volume of sealed pores*.

The *volume shrinkage* is obtained by subtracting the external volumes (*i.e.* values of $\dfrac{W - S}{\delta}$ before and after the heat treatment. To show progressive changes in the several volumes, all volumes are referred back to the original exterior volume of the test-piece as 100, and following this the results are given as the average of the five test-pieces for each heat treatment.

STANDARD TEST FOR SOFTENING POINT (REFRACTORINESS) OF FIREBRICK, Etc.

(American Society for Testing Materials, 1920.)

The softening point of fireclay brick, etc., is determined by comparison of test cones with standard Orton pyrometric cones in a suitable furnace.

A sample of approximately 1 kg. is taken by chipping off roughly equal pieces from corners of the brick. The sample is crushed so that the pieces have a maximum diameter of 5 mm., and is then quartered twice to reduce to approximately 250 grm. Metallic iron is removed from the sample by means of a magnet, and the sample is then ground in an agate or porcelain mortar to pass a standard 60-mesh sieve. During the grinding the finer particles are frequently removed by means of the sieve, to prevent their excessive reduction in size. The fine sample is then thoroughly mixed, and after addition of sufficient dextrine or glue and water, is formed into test cones in a metal mould, in the shape of a tetrahedron, measuring 5 mm. at the side of the base, and 25 mm. high. The test cones are dried, and then baked at a temperature not exceeding 1300°C. to allow firm handling.

The test cones are mounted on placques of refractory material which will not affect the fusibility of the cones. (A mixture of equal parts of a good grade of china clay and fused alumina which will pass a 100-mesh sieve is satisfactory.) The cones are mounted with the base embedded approximately 1 mm. in the placque, and one face inclined at 75° with the horizontal. These cones are alternated with the Orton cones, so that Orton cones of successive numbers are opposite each other. The heating is carried out in a suitable furnace at a rate between 10°C. and 15°C. per minute after Orton cone No. 1 has softened. The furnace should have a neutral or oxidising atmosphere, and the flame should not strike the cones or the placque. The softening point of the cone is indicated by the top bending over, and is reported in terms of Orton cones, being that cone which most nearly corresponds in time of softening with the test cone. If the test cone softens later than one Orton cone, and earlier than the next, both cones are reported, e.g., cone No. 31-32.

Bloating, squatting or unequal fusion of small particles should be reported, also any peculiarity, such as if the test cone commences to bend at an early Orton cone, but is not properly softened until a considerably later one.

ANALYSIS OF PORTLAND CEMENT.

A. GROUNDS, B.Sc. Tech., A.I.C., Assoc. M.I.Min.E.

(1) Loss on ignition,

1·0 grm. of the sample is heated gently in a platinum crucible for 5 mins. and then at 800°C. (between a bright red heat and a dull orange) for 1 hour. After cooling and weighing the heating is continued until no further loss in weight occurs. The loss on ignition is due to the expulsion of water and carbon dioxide; the carbonate may be estimated by treating 2—5 grms. of the powdered cement with hydrochloric acid and absorbing the carbon dioxide (after passage through a silver-sulphate tube and a wash-bottle containing strong sulphuric acid) in a 40% solution of caustic potash, contained in a weighed potash bulb.

(2) Silica and insoluble matter.

(a). 0·5 grm. of cement is well stirred with 15 cc. water in a porcelain basin, 25 cc. of hydrochloric acid (Sp. Gr. 1·2) added, and boiled down carefully to about 10 cc. The basin is covered with a clock-glass, and the contents evaporated to dryness and baked for one hour at 180°C. When cool, the residue is treated with 25 cc. concentrated hydrochloric acid, warmed gently, and the clock-glass washed with hot distilled water. The precipitate is filtered off, washed, dried, ignited, and weighed, when the weight gives the silica and insoluble matter.

(b). (a) is repeated, but when filtering from silica and insoluble matter the washing is carried out by decantation, and any precipitate on the filter paper is washed back into the dish. The silica is dissolved out by boiling for half an hour with 25 cc. of a saturated solution of sodium carbonate. The insoluble matter is then rapidly filtered off, washed free from carbonate with boiling water, dried, ignited, and weighed.

The difference between (a) and (b) gives the amount of soluble silica, whilst (b) gives the insoluble matter.

(3) Alumina.

The filtrate from 2 (a) is oxidised with bromine in presence of ammonia, excess being expelled by boiling. The precipitate is filtered off, dissolved in hydrochloric acid, and reprecipitated with ammonia, to ensure that the precipitate is free from calcium. The precipitate is dried, ignited, and weighed as aluminium and iron oxides.

The alumina is obtained by subtracting from this figure the ferric oxide, determined as in (4).

4) Iron.

This is determined in the filtrate and washings from 2 (b), after precipitation of sulphates as barium sulphate, by titration with standard titanous chloride or titanous sulphate.

5) Lime.

Calcium is precipitated as oxalate in the filtrate and washings from (3), and is weighed as calcium oxide.

6) Magnesia.

The filtrate and washings from (5) are evaporated almost to dryness, 25 cc. of nitric acid (Sp. Gr. 1·5) added, and the liquid warmed gently to remove all traces of ammonium salts. The residue is treated with water and a few drops of hydrochloric acid, and 3 cc. of a 10% solution of ammonium chloride added. Excess ammonia is added together with a few drops of ammonium oxalate, the solution boiled, and any precipitate filtered off and added to the lime precipitate. Magnesium is then estimated in the filtrate by means of sodium phosphate.

7) Sulphur trioxide.

This is estimated in the filtrate and washings from 2 (b) by precipitation as barium sulphate.

8) Sulphur (as sulphide).

0·5 grm. of the cement is dissolved in a small amount of water and 25 cc. of concentrated nitric acid. The total sulphate is then determined, and by subtracting the sulphate found in (7) the amount of sulphate corresponding to the sulphide present.

9) Alkalies and Loss.

This is taken as the difference between 100% and the sum of the results obtained above.

If the percentage of alkalies is required for any special purpose, it must be determined by, e.g., the Laurence Smith process.

Rapid Determination of Lime in Portland Cement without the separation of alumina, ferric oxide, silica, &c.

0·5 grm. of the sample is mixed with 30 cc. of distilled water, 10—15 cc. concentrated hydrochloric acid added, and the mixture heated for about 10 minutes until all soluble matter is dissolved. The solution is then brought to the boil, and sufficient ammonia added to produce a slight permanent

precipitate. The solution is boiled again, and 10 cc. of a 10% solution of oxalic acid added. When the hydroxides of iron and alumina have dissolved and only a slight precipitate of calcium oxalate remains, 200 cc. of boiling water and 25 cc. of a saturated solution of ammonium oxalate added, and the mixture boiled for 5 mins. The precipitate is allowed to settle, and is filtered, and then washed ten times with small quantities of hot water, the paper being allowed to drain thoroughly each time. The precipitate is washed into a beaker with hot water, 5—10 cc. of dilute sulphuric acid added, the mixture heated to 80°C., and the liquid titrated with standard potassium permanganate.

5·64 grm. of potassium permanganate made up to a litre gives a solution of which 1 cc. = 0·005 grm. CaO.

British Standard Specifications for Portland Cement.

(May, 1915).

The limits allowed are as follows :—

(i) The percentage of insoluble residue shall not exceed 1·50%.

(ii) The percentage of magnesia shall not exceed 3·00%.

(iii) The percentage of total sulphur shall not exceed 2·75% SO_3.

(iv) The percentage of total loss on ignition shall not exceed 3·00%.

(v) The proportion of lime to silica and alumina, when calculated (in chemical equivalents) by the formula

$$\frac{CaO}{SiO_2 + Al_2O_3}$$

shall not exceed 2·85 nor be less than 2·0 ; this ratio is known as the hydraulic modulus.

Example. In a cement containing 63·28% lime, 21·6% silica. and 8·16% alumina, the proportion of lime to silica and alumina is as follows :—

$$\frac{CaO}{SiO_2 + Al_2O_3} = \frac{63·28/56}{21·6/60 + 8·16/102} = 2·5\%.$$

(vi) Residue on a 180^2 sieve must not exceed 12%.

(vii) Residue on a 76^2 sieve must not exceed 1%.

(viii) Specific Gravity of the cement shall be not less than 3·10.

Standard Specifications and Tests for Cement as approved by the American Society for Testing Materials, 1921.

Standard Specifications.

The limits allowed are as follows :

(1) Loss on ignition shall not exceed 4·00%.

(2) Insoluble residue shall not exceed 0·85%.

(3) Sulphuric anhydride shall not exceed 2·00% SO_3.

(4) Magnesia shall not exceed 5·00% MgO.

(5) The specific gravity shall not be less than 3·10 (3·07 for white Portland cement).

(6) The residue on a standard No. 200 sieve shall not exceed 22% by weight.

(7) A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

(8) The cement shall not develop initial set in less than 45 mins. when the Vicat needle is used, or 60 mins. when the Gillmore needle is used. Final set shall be attained within 10 hrs.

(9) The average tensile strength of not less than 3 standard mortar briquettes composed of one part cement and three parts standard sand shall not be less than 200 lbs. per sq. in. after standing one day in moist air and then six days in water, or less than 300 lbs. per sq. in. after standing one day in moist air followed by 27 days in water.

(10) The average strength of standard mortar at 28 days shall be higher than the strength at 7 days.

Analysis. (Summary of A.S.T.M. methods, 1921.)

(1) *Loss on ignition.*

1 grm. of cement is heated in a weighed covered platinum crucible, either set in an asbestos board at a full red heat for 15 mins. over an inclined blow-pipe flame, or in a muffle furnace at 900° to 1000°C. for 15 mins. In either case the loss in weight is checked by a second heating for 5 mins.

(2) *Insoluble residue.*

1 grm. of cement is warmed with 10 cc. of water and 5 cc. of concentrated hydrochloric acid until effervescence ceases, diluted to 50 cc., and digested until decomposition of the cement is complete. The residue is filtered, washed, and, together with the filter-paper, digested with 30 cc. of a 5% solution of sodium carbonate for 15 mins. The remaining residue is filtered, washed with cold water, then with a few drops of hot hydrochloric acid (1 : 9), and finally with hot water. The filter-paper and contents are ignited at red heat, and weighed as the insoluble residue.

(3) *Sulphuric anhydride.*

This is estimated in the acid filtrate and washings from the determination of insoluble residue by precipitation as barium sulphate.

(4) *Magnesia.*

0·5 grm. of cement is mixed with 10 cc. of water in a porcelain basin, 10 cc. of concentrated hydrochloric acid added, and the liquid evaporated to dryness and baked for 1 hr. at 150° to 200°C. The residue is digested for 10 mins. with 20 cc. of hydrochloric acid (1 : 1), and the silica filtered off and thoroughly washed. To the filtrate are added 5 cc. of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese present, then iron and aluminium are precipitated by means of ammonium hydroxide.

The iron and aluminium hydroxides are filtered off (filtrate A), and are dissolved in hydrochloric acid, re-precipitated with ammonium hydroxide and bromine water, and again filtered off. This filtrate is combined with filtrate A, the mixture brought to the boil, 25 cc. of a boiling saturated solution of ammonium oxalate added, and the boiling continued until the calcium oxalate is granular in form. After allowing to stand for 1 hr., the calcium oxalate is filtered off (filtrate B), ignited, redissolved in hydrochloric acid, and re-precipitated by means of ammonium hydroxide and ammonium oxalate. The filtrate from this precipitate is combined with filtrate B, acidified with hydrochloric acid, concentrated to about 150 cc., made slightly alkaline with ammonium hydroxide, boiled, and filtered if necessary. The filtrate is cooled, 10 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added with stirring, and when the magnesium is precipitated as ammonium-magnesium orthophosphate, excess of ammonia is added, and the solution allowed to stand for several hours. The magnesium precipitate is filtered off, washed with water containing 2·5% of ammonia, then is re-dissolved, re-precipitated, filtered, and washed as previously. The precipitate is ignited to constant weight over a Méker burner, and the final weight of magnesium pyrophosphate, multiplied by 72·5, gives the % MgO present.

(5) *Specific gravity.*

This is determined on 64 grm. of cement by means of a Le Chatelier apparatus, as standardized by the Bureau of Standards.

(6) *Fineness.*

This is determined on 50 grm. of cement, using a No. 200 sieve, as standardized by the Bureau of Standards.

For description of physical tests and apparatus, see "A.S.T.M. Standards," 1921.

Percentage Composition of Various Portland Cements.

Brand of cement.	CaO	Al₂O₃	Fe₂O₃	MgO	SiO₂	Insol. residue	SO₃	Loss on ignition.	S as sulphide.	Alkalies and loss.	Hydraulic modulus.	Observer.
British, Rotary kiln, No. 1 ..	62.67	6.66	3.22	0.98	20.76	0.80	1.81	1.46	0.39	1.25	2.72	Grounds
British, Rotary kiln, No. 2 ..	62.95	6.35	3.95	1.63	21.09	0.51	1.45	1.18	0.32	0.57	2.71	
British, Ship Canal P.C. Co.	62.05	6.72	2.93	2.26	21.35	0.58	1.31	1.25	0.21	1.34	2.63	
British, Wiggins' P.C.	62.47	8.15	2.30	1.55	20.18	0.67	1.81	2.34	0.00	0.53	2.70	Miskin
Russian	63.40	5.01	2.30	0.92	23.97	1.04	0.81	1.85	0.38	0.32	2.52	Grounds
Chicago, AA.	61.95	7.67	2.61	2.82	20.05	0.71	1.68	0.29	0.04	2.18	2.70	,,
Atlas (U.S.A.)	60.89	8.03	2.94	2.05	22.01	0.42	1.07	0.03	0.62	1.94	2.64	,,
*Sandusky (U.S.A.) ..	62.38	6.16	2.90	1.21	23.08	–	1.66	–	–	3.61	2.50	Booth, Garrett & Blair.
Condlot (French)	62.80	8.50	3.10	0.45	22.30	–	0.70	–	–	2.15	2.46	Condlot.
Boulogne (French)	64.62	7.00	2.50	1.04	22.30	–	0.75	–	–	1.81	2.62	,,
Dyckerhoff	63.06	7.15	3.69	2.33	20.64	–	1.39	–	–	1.74	2.72	Booth, Garrett & Blair.
White Label, Alsen	64.30	7.28	3.88	1.76	20.48	–	2.46	–	–	1.84	2.78	,,

Analyses of American Portland Cements. (Richard K. Meade).

	SiO₂	Fe₂O₃	Al₂O₃	CaO	MgO	Alkalies	SO₃	Loss
Nazareth, Pa.	19.92	2.28	7.52	62.48	3.19	1.18	1.51	1.46
Nazareth, Pa.	21.14	2.30	6.94	63.24	3.26	0.87	1.12	1.24
Beth, Pa.	19.64	2.80	7.52	62.31	3.04	—	1.60	1.48
Alpha, N.J.	21.82	2.51	8.03	62.19	2.71	—	1.02	1.05
Northampton, Pa.	21.94	2.37	6.87	60.25	2.78	1.48	1.38	3.55
Coplay, Pa.	22.26	2.10	5.36	63.32	3.81	—	0.89	1.24
Omrod, Pa.	22.20	2.27	6.69	62.61	3.00	0.93	1.32	1.56
Martin's Creek, Pa.	20.32	2.50	7.12	62.94	3.38	—	1.45	1.25
Reading, Pa.	24.16	1.45	5.10	62.95	3.12	0.71	1.35	1.40
Bay City, Mich.	20.72	2.85	7.17	62.64	1.97	0.60	1.42	2.58
Wellston, O.	21.84	5.05	6.77	62.66	0.80	—	1.24	—
Chanute, Kan.	20.74	3.72	7.06	62.76	1.78	0.64	1.12	1.40
Ada, Okla.	12.28	3.20	6.36	59.66	3.11	1.05	1.40	2.82
Alsen, N.Y.	23.94	3.20	5.62	62.32	1.77	—	0.90	1.68
Fordwick, Va.	21.31	2.81	6.54	63.01	2.71	—	1.42	2.01
Davenport, Cal.	25.38	1.20	3.34	62.96	1.20	—	0.35	4.58
Cement, Cal.	22.34	3.30	7.00	60.72	1.30	—	1.05	2.54
St. Louis, Mo.	23.12	2.49	6.18	63.47	0.88	—	1.34	1.81
Demopolis, Ala.	19.36	4.10	9.18	63.20	1.16	—	1.18	1.12
Sandusky, O.	21.93	2.35	5.99	62.92	1.10	0.90	1.55	2.92
Chicago, Ill.	22.41	2.51	8.12	62.01	1.68	—	1.40	1.02
Chicago, Ill.	23.06	2.88	6.12	62.10	1.88	0.94	1.57	—

ACID AND ALKALI MANUFACTURE.

Sulphuric Acid.

Valuation of Sulphur. 50 grm. of the powdered sulphur are digested with 200 cc. of carbon disulphide (purified by distilling over mercury and mercury oxide), and the Specific Gravity of the solution determined. The % sulphur by volume found from the following table is multiplied by 4 to obtain the sulphur content of the sample. The ash is determined by igniting 10 grm. in a tared porcelain dish.

Specific Gravity of Solutions of Sulphur in Carbon Disulphide at $15°$ C. (Macagno).

Sp. Gr.	% S.	Sp. Gr.	% S.	Sp. Gr.	% S.	Sp. Gr.	% S.
1.271	0	1.301	7.2	1.331	14.5	1.361	22.1
72	0.2	02	7.5	32	14.7	62	22.3
73	0.4	03	7.8	33	15.0	63	22.7
74	0.6	04	8.0	34	15.2	64	23.0
75	0.9	05	8.2	35	15.4	65	23.2
76	1.2	06	8.5	36	15.6	66	23.6
77	1.4	07	8.7	37	15.9	67	24.0
78	1.6	08	8.9	38	16.1	68	24.3
79	1.9	09	9.2	39	16.4	69	24.8
80	2.1	10	9.4	40	16.6	70	25.1
81	2.4	11	9.7	41	16.9	71	25.6
82	2.6	12	9.9	42	17.1	72	26.0
83	2.9	13	10.2	43	17.4	73	26.5
84	3.1	14	10.4	44	17.6	74	26.9
85	3.4	15	10.6	45	17.9	75	27.4
86	3.6	16	10.9	46	18.1	76	28.1
87	3.9	17	11.1	47	18.4	77	28.5
88	4.1	18	11.3	48	18.6	78	29.0
89	4.4	19	11.6	49	18.9	79	29.7
90	4.6	20	11.8	50	19.0	80	30.2
91	4.8	21	12.1	51	19.3	81	30.8
92	5.1	22	12.3	52	19.6	82	31.4
93	5.3	23	12.6	53	19.9	83	31.9
94	5.6	24	12.8	54	20.1	84	32.6
95	5.8	25	13.1	55	20.4	85	33.2
96	6.0	26	13.3	56	20.6	86	33.8
97	6.3	27	13.5	57	21.0	87	34.5
98	6.5	28	13.8	58	21.2	88	35.2
99	6.7	29	14.0	59	21.5	89	36.1
1.300	7.0	30	14.2	60	21.8	90	36.7

W

Valuation of Pyrites.

Moisture is determined at 105°C. in 5 grm. of the sample.

0·5 grm. of the finely powdered sample is treated with 10 cc. of a mixture of 1 volume of concentrated hydrochloric acid and 3 volumes of concentrated nitric acid. After evaporating on the water-bath, the residue is treated with hydrochloric acid, again evaporated, and extracted with dilute hydrochloric acid and then with hot water. Ammonia is added to the warm filtrate to precipitate iron. The filtrate is acidified with hydrochloric acid, evaporated to 200 cc., and a moderate excess of a boiling solution of barium chloride, containing hydrochloric acid, added to the warm solution. After digesting on the water-bath for fifteen minutes, the precipitated barium sulphate is washed with hot water by decantation, filtered off, ignited, and weighed.

An alternative dry method for sulphur is to mix 0·5 grm. of the finely powdered sample with 5 grm. of sodium peroxide in a nickel crucible which has been coated inside with a layer of fused caustic soda. The crucible is heated gently until the vigorous reaction commences. The melt is extracted with water, and acidified with hydrochloric acid. Further procedure is as above.

Spanish pyrites contains 3–4 per cent. of copper, which may be determined as follows : 5 grm. of the finely powdered sample are dissolved carefully in 60 cc. of nitric acid (Sp. Gr. 1·2) and the liquid evaporated until white fumes are evolved. The residue is dissolved in 50 cc. of concentrated hydrochloric acid, and the solution boiled after addition f 2 grm. of sodium hypophosphite to remove arsenic and reduce any ferric salt present. The copper and lead are precipitated as sulphides by hydrogen sulphide or sodium thiosulphate, the sulphide precipitate dissolved in nitric acid, and lead removed from the solution by evaporating with sulphuric acid. The copper in the filtrate is estimated by thiosulphate or by the electrolytic method (see Vol. I); in the latter case, 0·01 per cent. is subtracted from the copper content so obtained to correct for the antimony and bismuth present.

Arsenic is estimated by dissolving 0·5 grm. of the sample in nitric acid, evaporating to dryness after adding 4 grm. of sodium carbonate, and fusing with 4 grm. of potassium nitrate. The melt is extracted with hot water, acidified, carbon dioxide boiled off, the liquid neutralised with ammonia, and silver nitrate added. The silver arsenate is filtered off, dissolved in nitric acid, and the silver in the solution estimated.

Sulphuric Acid.

(W. C. Ferguson and H. P. Talbot)

Adopted by the Manufacturing Chemists' Association of the U.S., 1904.

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%H_2SO_4		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F}$	%H_2SO_4
0	1.0000	0.00	......	30	1.2609	34.63
1	1.0069	1.02	......	31	1.2719	35.93
2	1.0140	2.08	......	32	1.2832	37.26
3	1.0211	3.13	..... .	33	1.2946	38.58
4	1.0284	4.21	......	34	1.3063	39.92
5	1.0357	5.28	......	35	1.3182	41.27
6	1.0432	6.37	......	36	1.3303	42.63
7	1.0507	7.45	......	37	1.3426	43.99
8	1.0584	8.55	.. ...	38	1.3551	45.35
9	1.0662	9.66	......	39	1.3679	46.72
10	1.0741	10.77	.. ...	40	1.3810	48.10
11	1.0821	11.89	.. ....	41	1.3942	49.47
12	1.0902	13.01	......	42	1.4078	50.87
13	1.0985	14.13	......	43	1.4216	52.26
14	1.1069	15.25	......	44	1.4356	53.66
15	1.1154	16.38	......	45	1.4500	55.07
16	1.1240	17.53	......	46	1.4646	56.48
17	1.1328	18.71	......	47	1.4796	57.90
18	1.1417	19.89	......	48	1.4948	59.32
19	1.1508	21.07	......	49	1.5104	60.75
20	1.1600	22.25	......	50	1.5263	62.18
21	1.1694	23.43	......	51	1.5422	63.36
22	1.1789	24.61	......	52	1.5591	65.61
23	1.1885	25.81	......	53	1.5761	66.63
24	1.1983	27.03	. ....	54	1.5934	68.13
25	1.2083	28.28	. ....	55	1.6111	69.65
26	1.2185	29.53	......	56	1.6292	71.17
27	1.2288	30.79	......	57	1.6477	72.75
28	1.2393	32.05	......	58	1.6667	74.36
29	1.2500	33.33	. ....	59	1.6860	75.99

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%H$_2$SO$_4$	°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%H$_2$SO$_4$
60	1.7059	77.67	64¼	1.7957	86.33
61	1.7262	79.43	64½	1.8012	87.04
62	1.7470	81.30	64¾	1.8068	87.81
63	1.7683	83.34	65	1.8125	88.65
64	1.7901	85.86	65¼	1.8182	89.55
			65½	1.8239	90.60
			65¾	1.8297	91.80
			66	1.8354	93.19

ALLOWANCE FOR TEMPERATURES.

At 10° Bé. correction of   .029° Bé. or .00023 Sp. Gr. for every 1° F.

At 20° Bé. correction of   .036° Bé. or .00034 Sp. Gr. for every 1° F.

At 30° Bé. correction of   .035° Bé. or .00039 Sp. Gr. for every 1° F.

At 40° Bé. correction of   .031° Bé. or .00041 Sp. Gr. for every 1° F.

At 50° Bé. correction of   .028° Bé. or .00045 Sp. Gr. for every 1° F

At 60° Bé. correction of   .026° Bé. or .00053 Sp. Gr. for every 1° F.

At 63° Bé. correction of   .026° Bé. or .00057 Sp. Gr. for every 1° F.

At 66° Bé correction of   .0235° Bé. or .00054 Sp. Gr. for every 1° F.

For temperatures above 60° F., the correction is added to the observed indication; below 60°F.. subtracted.

Analysis of Oleum.

I. Free SO_3.

(*a*) 20% oleum. A quantity of the oleum is drawn up into a Lunge weighing pipette and the pipette is weighed. About 2 grm. of the oleum is then dropped into 200—300 cc. of water, the pipette is re-weighed, and the acid titrated with normal caustic soda solution, using methyl orange as indicator.

(*b*) 65% oleum. A bulb about $\frac{1}{2}''$ diam. is blown on to the end of a piece of thin glass tubing, which is then drawn out to form a narrow stem about 3″ long. The bulb is weighed and the open end of the stem placed below the surface of the oleum. The bulb is gently heated to expel some of the air, and then allowed to cool so that 2—3 grm. of the oleum enters the bulb. The stem is then sealed and dried, the bulb is re-weighed, and introduced into a stoppered bottle containing about 300 cc. of water. The stopper is fitted firmly, and the bottle shaken thoroughly until the bulb is broken and all white fumes are absorbed. The acid is then titrated with normal caustic soda using methyl orange as indicator.

Example.

Weight of fuming acid = 1·5125 grm.

N caustic soda required (1 cc. = 0·04 grm. SO_3) = 33·6 cc.
$$= 1·344 \text{ grm. } SO_3.$$

H_2O combined with SO_3 = 1·5125 − 1·344 = 0·1685 grm.

Amount of SO_3 required to combine with 0·1685 grm.
$H_2O = 0·1685 \times 80/18 = 0·749$ grm. SO_3.

Free $SO_3 = 1·344 \quad - 0·749 = 0·595$ grm. SO_3.

$$\% \text{ Free } SO_3 = \frac{0·595 \times 100}{1·5125} = 39·3\%$$

II. Sulphur dioxide.

10 cc. of the oleum is run slowly into about 500 cc. of water, the acid almost neutralised with sodium carbonate, and the liquid made neutral with sodium bicarbonate. The sulphur dioxide is then estimated by titration with deci-normal iodine solution.

III. Nitric acid

This is usually estimated in 5 or 10 cc. of the oleum in a nitrometer (see "Gas Analysis" section). Using 5 cc. of the oleum at the ordinary temperature it may be taken that

$$1 \text{ cc. NO gas} = 0·029\% \text{ } HNO_3.$$

Percentage of SO₃ in Fuming Sulphuric Acid.

% Free $SO_3 = (\%$ found by titrating $- 81.6326) \times 5.4444$;
or, more accurately, $= (\%$ found by titrating $- 81.6306) \times 5.4438$.

Found by Titrating SO₃	H₂SO₄	Contains % Free SO₃	Found by Titrating SO₃	H₂SO₄	Contains % Free SO₃	Found by Titrating SO₃	H₂SO₄	Contains % Free SO₃
81.6326	100	0	87.8775	66	34	94.1224	32	68
81.8163	99	1	88.0612	65	35	94.3061	31	69
82.0000	98	2	88.2448	64	36	94.4897	30	70
82.1836	97	3	88.4285	63	37	94.6734	29	71
82.3674	96	4	88.6122	62	38	94.8571	28	72
82.5510	95	5	88.7959	61	39	95.0408	27	73
82.7346	94	6	88.9795	60	40	95.2244	26	74
82.9183	93	7	89.1632	59	41	95.4081	25	75
83.1020	92	8	89.3469	58	42	95.5918	24	76
83.2857	91	9	89.5306	57	43	95.7755	23	77
83.4693	90	10	89.7142	56	44	95.9591	22	78
83.6530	89	11	89.8979	55	45	96.1428	21	79
83.8367	88	12	90.0816	54	46	96.3265	20	80
84.0204	87	13	90.2653	53	47	96.5102	19	81
84.2040	86	14	90.4489	52	48	96.6938	18	82
84.3877	85	15	90.6326	51	49	96.8775	17	83
84.5714	84	16	90.8163	50	50	97.0612	16	84
84.7551	83	17	91.0000	49	51	97.2448	15	85
84.9387	82	18	91.1836	48	52	97.4285	14	86
85.1224	81	19	91.3673	47	53	97.6122	13	87
85.3061	80	20	91.5510	46	54	97.7959	12	88
85.4897	79	21	91.7346	45	55	97.9795	11	89
85.6734	78	22	91.9183	44	56	98.1632	10	90
85.8571	77	23	92.1020	43	57	98.3469	9	91
86.0408	76	24	92.2857	42	58	98.5306	8	92
86.2244	75	25	92.4693	41	59	98.7142	7	93
86.4081	74	26	92.6530	40	60	98.8979	6	94
86.5918	73	27	92.8367	39	61	99.0816	5	95
86.7755	72	28	93.0204	38	62	99.2753	4	96
86.9591	71	29	93.2040	37	63	99.4489	3	97
87.1428	70	30	93.3877	36	64	99.6326	2	98
87.3265	69	31	93.5714	35	65	99.8163	1	99
87.5102	68	32	93.7551	34	66			
87.6938	67	33	93.9389	33	67			

Boiling-points of Various Concentrations of Sulphuric Acid (Lunge).

% H$_2$SO$_4$	Sp. Gr.	B.Pt.	% H$_2$SO$_4$	Sp. Gr	B.Pt.
5	1.031	101° C	70	1.615	170° C.
10	1.069	102	72	1.639	174.5
15	1.107	103.5	74	1.661	180.5
20	1.147	105	76	1.688	189
25	1.184	106.5	78	1.710	199
30	1.224	108	80	1.733	207
35	1.265	110	82	1.758	218.5
40	1.307	114	84	1.773	227
45	1.352	118.5	86	1.791	238.5
50	1.399	124	88	1.807	251.5
53	1.428	128.5	90	1.818	262.5
56	1.459	133	91	1.824	268
60	1.503	141.5	92	1.830	274.5
62.5	1.530	147	93	1.834	281.5
65	1.557	153.5	94	1.837	288.5
67.5	1.585	161	95	1.840	295

Boiling-point of Concentrated Sulphuric Acid and of Oleum (Knietsch).

% H$_2$SO$_4$	Total SO$_3$ %	Free SO$_3$ %	B.Pt.°C. at	mm.
61.69	50.36	–	140	750
70.90	57.88	–	162	750
81.49	66.44	–	202	750
89.23	72.84	–	240	750
96.26	78.56	–	292	750
98.54	80.44	–	317	750
99.91	81.56	–	273	753
–	82.3	3.64	212	759
–	83.4	9.63	170	759
–	86.45	26.23	125	759
–	89.5	42.84	92	759
–	93.24	63.20	60	759
–	99.5	97.2	43	759

Solidifying point of Sulphuric Acid and Oleum.

Sulphuric acid						Oleum		
% SO_3	% H_2SO_4	S.pt °C.	% SO_3	% H_2SO_4	S.pt °C	% SO_3	% Free SO_3	S.pt °C.
1	1.22	− 0.6	61	74.72	− 40.0	81.6	0	+10.0
2	2.45	− 1.0	62	75.95	− 20.0	82.6	5	+ 3.5
3	3.68	− 1.7	63	77.18	− 11.5	83.5	10	− 4.8
4	4.90	− 2.0	64	78.40	− 4.8	84.4	15	−11.2
5	6.13	− 2.7	65	79.63	− 4.2	85.3	20	−11.0
6	7.35	− 3.6	66	80.85	+ 1.2	86.2	25	− 0.6
7	8.58	− 4.4	67	82.08	+ 8.0	87.1	30	+15.2
8	9.80	− 5.3	68	83.39	+ 8.0	88.1	35	+26.0
9	11.03	− 6.0	69	84.53	+ 7.0	89.0	40	+33.8
10	12.25	− 6.7	70	85.75	+ 4.0	89.9	45	+34.8
11	13.47	− 7.2	71	86.97	− 1.0	90.8	50	+28.5
12	14.70	− 7.9	72	88.20	− 7.2	91.7	55	+18.4
13	15.92	− 8.2	73	89.43	− 16.2	92.7	60	+ 0.7
14	17.15	− 9.0	74	90.65	− 25.0	93.6	65	+ 0.8
15	18.58	− 9.3	75	91.87	− 34.0	94.5	70	+ 9.0
16	19.60	− 9.8	76	93.10	− 32.0	95.4	75	+17.2
17	20.82	−11.4	77	94.83	− 28.2	96.3	80	+22.0
18	22.05	−13.2	78	95.05	− 16.5	97.2	85	+33.0
19	23.27	−15.2	79	96.78	− 5.2	98.2	90	+34.0
20	24.50	−17.1	80	98.00	+ 3.0	99.1	95	+36.0
21	25.72	−22.5	81	99.25	+ 7.0	100.0	100	+40.0
22	26.95	−31.0	81.63	100.00	+10.0			
23	28.17	−40.1						

Preparation of Fuming Sulphuric Acid of required strength.

Gnehm gives the following formula : $\quad x = 100 \dfrac{b - a}{a - c}$

where x = amount of ordinary sulphuric acid to be added to 100 parts of the fuming acid available,

a = total SO_3 per cent. in the required acid,

b = „ „ „ fuming acid available,

c = SO_3 in the ordinary sulphuric acid = $0.816 \times$ % H_2SO_4.

Gerster gives the following formula :—

$$x = \frac{100 (a - b)}{444 + b - 4.44 c}$$

where x = amount of ordinary sulphuric acid to be added to 100 g. of the fuming acid available.

a = free SO_3 per cent. in the fuming acid available.

b = free SO_3 „ „ „ „ required.

c = H_2SO_4 „ „ ordinary sulphuric acid.

Nitric Acid.

(W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S., 1904.

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HNO₃.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HNO₃.
10.00	1.0741	12.86	......	25.00	1.2083	33.42
10.50	1.0781	13.49	......	25.50	1.2134	34.17
11.00	1.0821	14.13	......	26.00	1.2185	34.94
11.50	1.0861	14.76	......	26.50	1.2236	35.70
12.00	1.0902	15.41	......	27.00	1.2288	36.48
12.50	1.0943	16.05	......	27.50	1.2340	37.26
13.00	1.0985	16.72	......	28.00	1.2393	38.06
13.50	1.1027	17.38	......	28.50	1.2446	38.85
14.00	1.1069	18.04	......	29.00	1.2500	39.66
14.50	1.1111	18.70	......	29.50	1.2554	40.47
15.00	1.1154	19.36	......	30.00	1.2609	41.30
15.50	1.1197	20.02	......	30.50	1.2664	42.14
16.00	1.1240	20.69	......	31.00	1.2719	43.00
16.50	1.1284	21.36	......	31.50	1.2775	43.89
17.00	1.1328	22.04	......	32.00	1.2832	44.78
17.50	1.1373	22.74	......	32.50	1.2889	45.68
18.00	1.1417	23.42	......	33.00	1.2946	46.58
18.50	1.1462	24.11	......	33.50	1.3004	47.49
19.00	1.1508	24.82	......	34.00	1.3063	48.42
19.50	1.1554	25.53	......	34.50	1.3122	49.35
20.00	1.1600	26.24	......	35.00	1.3182	50.32
20.50	1.1647	26.96	......	35.50	1.3242	51.30
21.00	1.1694	27.67	......	36.00	1.3303	52.30
21.50	1.1741	28.36	......	36.50	1.3364	53.32
22.00	1.1789	29.07	......	37.00	1.3426	54.36
22.50	1.1837	29.78	......	37.50	1.3488	55.43
23.00	1.1885	30.49	......	38.00	1.3551	56.52
23.50	1.1934	31.21	......	38.50	1.3615	57.65
24.00	1.1983	31.94	......	39.00	1.3679	58.82
24.50	1.2033	32.68	......	39.50	1.3744	60.06

°Baumé.	Sp. Gr. $\frac{60°F}{60°F.}$	%HNO₃.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HNO₃.
40.00	1.3810	61.38	......	45.00	1.4500	77.17
40.25	1.3843	62.07	......	45.25	1.4536	78.07
40.50	1.3876	62.77	......	45.50	1.4573	79.03
40.75	1.3909	63.48	......	45.75	1.4610	80.04
41.00	1.3942	64.20	......	46.00	1.4646	81.08
41.25	1.3976	64.93	......	46.25	1.4684	82.18
41.50	1.4010	65.67	......	46.50	1.4721	83.33
41.75	1.4044	66.42	......	46.75	1.4758	84.48
42.00	1.4078	67.18	......	47.00	1.4796	85.70
42.25	1.4112	67.95	......	47.25	1.4834	86.98
42.50	1.4146	68.73	......	47.50	1.4872	88.32
42.75	1.4181	69.52	......	47.75	1.4910	89.76
43.00	1.4216	70.33	.....	48.00	1.4948	91.35
43.25	1.4251	71.15	......	48.25	1.4987	93.13
43.50	1.4286	71.98	......	48.50	1.5026	95.11
43.75	1.4321	72.82				
44.00	1.4356	73.67				
44.25	1.4392	74.53				
44.50	1.4428	75.40				
44.75	1.4464	76.28				

ALLOWANCE FOR TEMPERATURE.

At from 10° to 20° Bé. correction of 1/30° Bé
or .00029 Sp. Gr. for every 1° F.

At from 20° to 30° Bé. correction of 1/23° Bé.
or .00044 Sp. Gr. for every 1° F.

At from 30° to 40° Bé. correction of 1/20° Be.
or .00060 Sp. Gr. for every 1° F.

At from 40° to 48.5° Bé. correction of 1/17° Bé.
or .00084 Sp. Gr. for every 1° F.

Hydrochloric Acid.
(W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S., 1903.

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HCl.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HCl.
1.00	1.0069	1.40	......	16.70	1.1301	25.72
2.00	1.0140	2.82	......	16.80	1.1310	25.89
3.00	1.0211	4.25	......	16.90	1.1319	26.05
4.00	1.0284	5.69	......	17.00	1.1328	26.22
5.00	1.0357	7.15	......	17.10	1.1336	26.39
6.00	1.0432	8.64	......	17.20	1.1345	26.56
7.00	1.0507	10.17	......	17.30	1.1354	26.73
8.00	1.0584	11.71	......	17.40	1.1363	26.90
9.00	1.0662	13.26	......	17.50	1.1372	27.07
10.00	1.0741	14.83	......	17.60	1.1381	27.24
10.50	1.0781	15.62	......	17.70	1.1390	27.41
11.00	1.0821	16.41	......	17.80	1.1399	27.58
11.50	1.0861	17.21	......	17.90	1.1408	27.75
12.00	1.0902	18.01	......	18.00	1.1417	27.92
12.50	1.0943	18.82	......	18 10	1.1426	28.09
12.75	1.0964	19.22	......	18.20	1.1435	28.26
13.00	1.0985	19.63	......	18.30	1.1444	28.44
13.25	1.1006	20.04	......	18.40	1.1453	28.61
13.50	1.1027	20.45	......	18.50	1.1462	28.78
13.75	1.1048	20.86	......	18.60	1.1471	28.95
14.00	1.1069	21.27	......	18.70	1.1480	29.13
14.25	1.1090	21.68	......	18.80	1.1489	29.30
14.50	1.1111	22.09	......	18.90	1.1498	29.48
14.75	1.1132	22.50	......	19.00	1.1508	29.65
15.00	1.1154	22.92	......	19.10	1.1517	29.83
15.25	1.1176	23.33	......	19.20	1.1526	30.00
15.50	1.1197	23.75	......	19.30	1.1535	30.18
15.75	1.1219	24.16	......	19.40	1.1544	30.35
16.00	1.1240	24.57	......	19.50	1.1554	30.53
16.10	1.1248	24.73	......	19.60	1.1563	30.71
16.20	1.1256	24.90	......	19.70	1.1572	30.90
16.30	1.1265	25.06	......	19.80	1.1581	31.08
16.40	1.1274	25.23	......	19.90	1.1590	31.27
16.50	1.1283	25.39	......	20.00	1.1600	31.45
16.60	1.1292	25.56	......	20.10	1.1609	31.64

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HCl.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%HCl.
20.20	1.1619	31.82	......	22.20	1.1808	35.59
20.30	1.1628	32.01	......	22.30	1.1817	35.78
20.40	1.1637	32.19	......	22.40	1.1827	35.97
20.50	1.1647	32.38	......	22.50	1.1836	36.16
20.60	1.1656	32.56	......	22.60	1.1846	36.35
20.70	1.1666	32.75	......	22.70	1.1856	36.54
20.80	1.1675	32.93	......	22.80	1.1866	36.73
20.90	1.1684	33.12	......	22.90	1.1875	36.93
21.00	1.1694	33.31	......	23.00	1.1885	37.14
21.10	1.1703	33.50	......	23.10	1.1895	37.36
21.20	1.1713	33.69	......	23.20	1.1904	37.58
21.30	1.1722	33.88	......	23.30	1.1914	37.80
21.40	1.1732	34.07	......	23.40	1.1924	38.03
21.50	1.1741	34.26	......	23.50	1.1934	38.26
21.60	1.1751	34.45	......	23.60	1.1944	38.49
21.70	1.1760	34.64	......	23.70	1.1953	38.72
21.80	1.1770	34.83	......	23.80	1.1963	38.95
21.90	1.1779	35.02	......	23.90	1.1973	39.18
22.00	1.1789	35.21	......	24.00	1.1983	39.41
22.10	1.1798	35.40	......	24.10	1.1993	39.64

ALLOWANCE FOR TEMPERATURE.

At 10° to 15° Bé. correction of 1/40° Bé.
or .0002 Sp. Gr. for every 1° F.

At 10° to 22° Bé. correction of 1/30° Bé.
or .0003 Sp. Gr. for every 1° F.

At 22° to 25° Bé. correction of 1/28° Bé.
or .00035 Sp. Gr. for every 1° F.

Alkali Manufacture.

Table for Comparing Different Systems of Alkalimetry for Caustic Soda.

Caustic Soda % NaOH	Actual Alkali % Na$_2$O	Newcastle Test % Na$_2$O	N. Y. & Liv. % Na$_2$O
74.83	58.0	58.76	59.87
75.48	58.5	59.27	60.38
76.12	59.0	59.77	60.90
76.77	59.5	60.28	61.42
77.40	60.0	60.79	61.93
78.05	60.5	61.30	62.45
78.70	61.0	61.80	62.97
79.35	61.5	62.31	63.48
80.00	62.0	62.82	64.00
80.65	62.5	63.32	64.52
81.29	63.0	63.83	65.03
81.94	63.5	64.33	65.55
82.58	64.0	64.84	66.06
83.23	64.5	65.35	66.58
83.87	65.0	65.85	67.10
84.52	65.5	66.36	67.61
85.16	66.0	66.87	68.13
85.81	66.5	67.37	68.65
86.45	67.0	67.88	69.16
87.10	67.5	68.39	69.68
87.74	68.0	68.89	70.19
88.39	68.5	69.40	70.71
89.03	69.0	69.91	71.23
89.67	69.5	70.41	71.74
90.30	70.0	70.92	72.26
90.95	70.5	71.43	72.77
91.60	71.0	71.93	73.29
92.25	71.5	72.44	73.81
92.90	72.0	72.95	74.32
93.55	72.5	73.45	74.84
94.19	73.0	73.96	75.35
94.84	73.5	74.47	75.87
95.48	74.0	74.97	76.39
96.13	74.5	75.48	76.90
96.77	75.0	75.99	77.42
97.32	75.5	76.49	77.94
98.06	76.0	77.00	78.45
98.71	76.5	77.51	78.97
99.35	77.0	78.01	79.49
100.00	77.5	78.52	80.00

Commercial Alkalimetric Degrees.

Real soda (Gay-Lussac degrees)=percentage Na_2O (calculated to correct equivalent of Na_2CO_3, viz., 53.05).

English or Newcastle degrees=percentage Na_2O (calculated to an incorrect equivalent of Na_2CO_3, viz., 54).

German degrees=percentage Na_2CO_3.

Descroizilles degrees=amount of H_2SO_4 neutralised by 100 parts of alkali. (Used in France and Belgium.)

Table for Comparing Different Systems of Alkalimetry for Soda Ash.

Soda Ash %Na_2CO_3	Actual Alkali %Na_2O	Newcastle Test %Na_2O	N. Y. & Liv. % Na_2O
79.51	46.5	47.11	48.00
80.37	47.0	47.62	48.51
81.22	47.5	48.12	49.03
82.07	48.0	48.63	49.54
82.93	48.5	49.14	50.06
83.78	49.0	49.64	50.58
84.64	49.5	50.15	51.09
85.48	50.0	50.66	51.61
86.34	50.5	51.16	52.12
87.19	51.0	51.67	52.64
88.05	51.5	52.18	53.16
88.90	52.0	52.68	53.67
89.76	52.5	53.19	54.19
90.61	53.0	53.70	54.70
91.47	53.5	54.20	55.22
92.32	54.0	54.71	55.74
93.18	54.5	55.22	56.25
94.03	55.0	55.72	56.77
94.89	55.5	56.23	57.29
95.74	56.0	56.74	57.80
96.60	56.5	57.24	58.32
97.45	57.0	57.75	58.83
98.31	57.5	58.26	59.35
99.16	58.0	58.76	59.87
100.00	58.5	59.27	60.38

Valuation of Soda Ash. 25 grm. of soda ash are dissolved in water, and made up to 250 cc.

a) In presence of bicarbonate. 25 cc. of the solution are titrated in a porcelain dish with normal sulphuric acid, slowly and with stirring, with the point of the burette under the liquid, using phenolphthalein as indicator. As soon as carbonic acid is liberated the solution becomes colourless, that is, when the sodium carbonate has been converted into bicarbonate. Methyl orange is then added and the titration continued until the solution is acid. This converts all the bicarbonate (including that formed from the carbonate) into sulphate. The difference between the first and (larger) second volume will hence correspond to the bicarbonate present, and twice the first volume to the carbonate present.

(b) In presence of caustic soda. The above titrations are carried out. The first volume of acid used (with phenolphthalein) will be found to be larger than the second volume (using methyl orange). In this case the first volume corresponds to the neutralisation of the caustic soda and the conversion of the carbonate into bicarbonate. The difference between the two volumes hence corresponds to the caustic soda present, and twice the second volume to the carbonate present.

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Sodium Hydroxide Solutions.
(Lunge).

Sp. Gr. $\frac{60° F.}{60° F.}$	°Baumé.	°Twaddell.	% NaOH.	Grm. NaOH. per litre.
1.007	1.0	1.4	0.61	6
1.014	2.0	2.8	1.20	12
1.022	3.1	4.4	2.00	21
1.029	4.1	5.8	2.70	28
1.036	5.1	7.2	3.35	35
1.045	6.2	9.0	4.00	42
1.052	7.2	10.4	4.64	49
1.060	8.2	12.0	5.29	56
1.067	9.1	13.4	5.87	63
1.075	10.1	15.0	6.55	70

Sp. Gr. $\frac{60° F.}{60° F.}$	°Baumé.	°Twaddell.	% NaOH.	Grm. NaOH. per litre.
1.083	11.1	16.6	7.31	79
1.091	12.1	18.2	8.00	87
1.100	13.2	20.0	8.68	95
1.108	14.1	21.6	9.42	104
1.116	15.1	23.2	10.06	112
1.125	16.1	25.0	10.97	123
1.134	17.1	26.8	11.84	134
1.142	18.0	28.4	12.64	144
1.152	19.1	30.4	13.55	156
1.162	20.2	32.4	14.37	167
1.171	21.2	34.2	15.13	177
1.180	22.1	36.0	15.91	188
1.190	23.1	38.0	16.77	200
1.200	24.2	40.0	17.67	212
1.210	25.2	42.0	18.58	225
1.220	26.1	44.0	19.58	239
1.231	27.2	46.2	20.59	253
1.241	28.2	48.2	21.42	266
1.252	29.2	50.4	22.64	283
1.263	30.2	52.6	23.67	299
1.274	31.2	54.8	24.81	316
1.285	32.2	57.0	25.80	332
1.297	33.2	59.4	26.83	348
1.308	34.1	61.6	27.80	364
1.320	35.2	64.0	28.83	381
1.332	36.1	66.4	29.93	399
1.345	37.2	69.0	31.22	420
1.357	38.1	71.4	32.47	441
1.370	39.2	74.0	33.69	462
1.383	40.2	76.6	34.96	483
1.397	41.2	79.4	36.25	506
1.410	42.2	82.0	37.47	528
1.424	43.2	84.8	38.80	553
1.438	44.2	87.6	39.99	575
1.453	45.2	90.6	41.41	602
1.468	46.2	93.6	42.83	629
1.483	47.2	96.6	44.38	658
1.498	48.2	99.6	46.15	691
1.514	49.2	102.8	47.60	721
1.530	50.2	106.0	49.02	750

Potassium Hydroxide Solutions.

(Lunge).

Sp. Gr $\frac{60° F.}{60° F.}$	°Baumé.	°Twaddell.	% KOH.	Grm. KOH. per litre
1.007	1.0	1.4	0.9	9
1.014	2.0	2.8	1.7	17
1.022	3.1	4.4	2.6	26
1.029	4.1	5.8	3.5	36
1.037	5.2	7.4	4.5	46
1.045	6.2	9.0	5.6	58
1.052	7 2	10.4	6.4	67
1.060	8.2	12.0	7.4	78
1.067	9.1	13.4	8.2	83
1.075	10.1	15.0	9.2	99
1.083	11.1	16.6	10.1	109
1.091	12.1	18.2	10.9	119
1.100	13.2	20.0	12.0	132
1.108	14.1	21.6	12.9	143
1.116	15.1	23.2	13.8	153
1.125	16.1	25.0	14.8	167
1.134	17.1	26.8	15.7	178
1.142	18.0	28.4	16.5	183
1.152	19.1	30.4	17.6	203
1.162	20.2	32.4	18.6	216
1.171	21.2	34.2	19.5	228
1.180	22.1	36.0	20.5	242
1.190	23.1	38.0	21.4	255
1.200	24.2	40.0	22.4	269
1.210	25.2	42.0	23.3	282
1.220	26.1	44.0	24.2	295
1.231	27.2	46.2	25.1	309
1.241	28.2	48.2	25.1	324
1.252	29.2	50.4	27.0	338

Sp. Gr. $\frac{60° \text{ F.}}{60° \text{ F.}}$	°Baumé.	°Twaddell.	% KOH.	Grm. KOH. per litre.
1.263	30.2	52.6	28.0	353
1.274	31.2	54.8	28.9	368
1.285	32.2	57.0	29.8	385
1.297	33.2	59.4	30.7	398
1.308	34.1	61.6	31.8	416
1.320	35.2	64.0	32.7	432
1.332	36.1	66.4	33.7	449
1.345	37.2	69.0	34.9	469
1.357	38.1	71.4	35.9	487
1.370	39.2	74.0	36.9	506
1.383	40.2	76.6	37.8	522
1.397	41.2	79.4	38.9	543
1.410	42.2	82.0	39.9	563
1.424	43.2	84.8	40.9	582
1.438	44.2	87.6	42.1	605
1.453	45.2	90.6	43.4	631
1.468	46.2	93.6	44.6	655
1.483	47.2	96.6	45.8	679
1.498	48.2	99.6	47.1	706
1.514	49.2	102.8	48.3	731
1.530	50.2	106.0	49.4	756
1.546	51.2	109.2	50.6	779
1.563	52.2	112.6	51.9	811
1.580	53.2	116.0	53.2	840
1.597	54.2	119.4	54.5	870
1.615	55.2	123.0	55.9	905
1.634	56.3	126.8	57.5	940

Ammonia Solutions.

(W. C. Ferguson).

Adopted by the Manufacturing Chemists' Association of the U.S. 1903.

Sp. Gr. °Baumé.	°Baumé.	$\frac{60°F.}{60°F.}$	%NH₃.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%NH₃.
10.00	1.0000	.00	......	18.75	.9412	15.37
10.25	.9982	.40	......	19.00	.9396	15.84
10.50	.9964	.80	......	19.25	.9380	16.32
10.75	.9947	1.21	......	19.50	.9365	16.80
11.00	.9929	1.62	......	19.75	.9349	17.28
11.25	.9912	2.04	......	20.00	.9333	17.76
11.50	.9894	2.46	......	20.25	.9318	18.24
11.75	.9876	2.88	......	20.50	.9302	18.72
12.00	.9859	3.30	......	20.75	.9287	19.20
12.25	.9842	3.73	......	21.00	.9272	19.68
12.50	.9825	4.16	......	21.25	.9256	20.16
12.75	.9807	4.59	......	21.50	.9241	20.64
13.00	.9790	5.02	......	21.75	.9226	21.12
13.25	.9773	5.45	......	22.00	.9211	21.60
13.50	.9756	5.88	......	22.25	.9195	22.08
13.75	.9739	6.31	......	22.50	.9180	22.56
14.00	.9722	6.74	......	22.75	.9165	23.04
14.25	.9705	7.17	......	23.00	.9150	23.52
14.50	.9689	7.61	......	23.25	.9135	24.01
14.75	.9672	8.05	......	23.50	.9121	24.50
15.00	.9655	8.49	......	23.75	.9106	24.99
15.25	.9639	8.93	......	24.00	.9091	25.48
15.50	.9622	9.38	......	24.25	.9076	25.97
15.75	.9605	9.83	......	24.50	.9061	26.46
16.00	.9589	10.28	......	24.75	.9047	26.95
16.25	.9573	10.73	......	25.00	.9032	27.44
16.50	.9556	11.18	......	25.25	.9018	27.93
16.75	.9540	11.64	......	25.50	.9003	28.42
17.00	.9524	12.10	......	25.75	.8989	28.91
17.25	.9508	12.56	......	26.00	.8974	29.40
17.50	.9492	13.02	......	26.25	.8960	29.89
17.75	.9475	13.49	......	26.50	.8946	30.38
18.00	.9459	13.96	......	26.75	.8931	30.87
18.25	.9444	14.43	......	27.00	.8917	31.36
18.50	.9428	14.90	......	27.25	.8903	31.85

°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%NH₃.		°Baumé.	Sp. Gr. $\frac{60°F.}{60°F.}$	%NH₃.
27.50	.8889	32.34	......	28.50	.8833	34.30
27.75	.8875	32.83	......	28.75	.8819	34.79
28.00	.8861	33.32	......	29.00	.8805	35.28
28.25	.8847	33.81				

ALLOWANCE FOR TEMPERATURE.

The coefficient of expansion for ammonia solutions, varying with the temperature, correction must be applied according to the following table :—

Degrees °Baumé.	Corrections to be Added for Each Degree Below 60° F.		Corrections to be Subtracted for Each Degree Above 60° F.			
	40° F.	50° F.	70° F.	80° F.	90° F.	100° F.
Bé.	Bé.	Bé.	Bé	Bé	Bé	Bé
14°	.015°	017°	020°	.022°	.024°	.026°
16°	.021°	.023°	.026°	.028°	.030°	.032°
18°	.027°	.029°	.031°	.033°	.035°	.037°
20°	.033°	.036°	.037°	.038°	.040°	.042°
22°	.039°	.042°	.043°	.045°	.047°	
26°	.053°	.057°	057°	.059°		

OILS AND FATS.

Examination of Oils and Fats.

1. *Specific Gravity*. This is determined by means of a pyknometer or Westphal balance, fats at 100°C. and oils at 15°C. A correction of ±·00064 is made for each degree Centigrade.

2. *Melting point*. A small quantity of the melted and filtered fat is introduced into a piece of capillary tubing, one end of which is sealed, and the melting point determined in the usual manner. An alternative method is to place a small piece of the fat on mercury contained in a crucible, and determine the temperature of the mercury at which the fat melts.

3. *Solidifying point of fatty acids* (Titer test). When a fat is allowed to solidify, the temperature frequently rises slightly during the short period in which the fat is actually changing from the liquid to the solid state owing to the latent heat being set free. In the case of solidification of fatty acids, the highest point of this rise in temperature is known as the Titer.

52 grm. of fat are saponified with 40 cc. of caustic soda solution (56° Tw.) and 50 cc. of alcohol, and evaporated until almost dry. The soap is dissolved in one litre of hot water, and the fatty acid liberated by the addition of 60 cc. of sulphuric acid (1 : 4 by volume). The whole is then boiled until the fatty acids form a perfectly clear layer on top. The acid liquor is run off, and the fatty acids washed free from mineral acid with hot water. The fatty acids are separated from the water, dried in a water-bath for an hour, transferred to a Titer-tube, and allowed to solidify, the temperature being taken by means of a thermometer graduated in fifths of a degree. When the temperature becomes constant, rises, and falls again, the highest point attained is the Titer of the fatty acids.

4. *Refractivity* is determined by means of the Abbé Refractometer.

5. *Water*. For a rapid test on neutral fats, 5 to 10 grm. are heated to 110°C. in a crucible, the fat being stirred with

a very small thermometer. Loss in weight at 110° is taken as water.

The test most frequently used is to heat 5 to 10 grm. of fat for one hour in an air-oven at 95°C.

The xylene method is more accurate. About 50 grams of fat are mixed with 50 cc. of xylene in a distillation flask. The flask is heated, and the distillate collected in a bulb-tube with a long constriction at the lower end, graduated in tenths of a cc. The first portion of the distillate contains all the water, and the distillation is continued until the B.Pt. of pure xylene is attained, and the condenser has been well washed with xylene vapour. On allowing to stand for 3 or 4 hours, all the water separates from the distillate, the volume is measured, and the percentage of water is calculated on the weight of fat used.

Acid fats are heated in a stream of dry carbon dioxide at 105° to 110°C., and loss in weight is accepted as water. They may also be tested directly by the xylene method.

6. *Ash.* About 5 grm. of fat are burnt in a porcelain or platinum crucible, and heated until all the carbon has burnt off. The ash may be analysed by the usual method.

7. *Insoluble matter and dirt.* 20 grm. of the evenly mixed fat are dissolved in about 100 cc. of petroleum ether. The solution is filtered through a weighed filter-paper, which is washed free from fat with petroleum ether, when a drop of the filtrate leaves no grease-spot on paper. The filter-paper is then re-weighed. The ash is subtracted from the total insoluble to give the *organic insoluble matter.*

8. *Unsaponifiable (e.g. mineral oil).* 5 grm. fat are saponified with 25 cc. 2N alcoholic potash on the water-bath. The soap is dissolved in water, and the solution shaken with two amounts of 50 cc. each distilled ethyl ether in two separating funnels. The clear ether extract is withdrawn, washed with water, and evaporated in a weighed flask. The insoluble matter is also saponified with alcoholic potash in exceptional cases.

9. *Total fat* The filtrate from (7) is evaporated and weighed, or 5 grm. fat are mixed with 4 to 6 times the amount of Calais sand dried at 100°C., and extracted with ether or petroleum ether. The disadvantage of the former is that it is slightly soluble in water, whilst the latter cannot be entirely removed from the fat. It is usual, however, to estimate the total fat by difference of water, ash, and insoluble matter from 100%.

10. *Free mineral acid.* The fat is shaken with warm water, and the water tested with methyl orange and titrated if necessary.

11. *Calcium soaps*, generally found in bone-fat. The insoluble residue from the petroleum ether solution (7) is washed from the filter into a tube, and decomposed with hydrochloric acid. The fatty acids are extracted with ether and weighed; from this the total calcium soaps may be calculated.

CONSTANTS OF OILS AND FATS.

1. The *Saponification value* is the number of milligrams of KOH required to saponify 1 grm. of the fat.

2·5 to 4 grm. of the fat are saponified with 50 cc. N/2 alcoholic potash (made by dissolving 30 grm. solid KOH in 1 litre of alcohol of Sp. Gr. 0·81, and, after one or two days, filtering through glass wool) on the water-bath under a reflux condenser for 30 minutes. Phenolphthalein is added and the solution titrated with N/2 hydrochloric acid. A blank test is carried out on another 50 cc. of the alcoholic potash, and the saponification value calculated from the figures so obtained.

In the case of dark-coloured fats, advantage is taken of the insolubility of the barium soap. 5 grm. of the fat are saponified with 50 cc. alcoholic potash, 50 cc. N/2 $BaCl_2$ solution and 300 cc. water added, and heated under a reflux condenser for 30 minutes. The baryta soap and foreign matter are precipitated, and if it is then impossible to titrate the solution directly, it is made up to 600 cc. with water, filtered through linen, and an aliquot portion titrated.

2. The *Iodine value* is the percentage of iodine with which the unsaturated acids of a fat will combine.

Hubl's method. 0·15 to 0·2 grm. of a drying oil, 0·3 to 0·4 grm. of a non-drying oil, or 0·8 to 1 grm. of a solid fat are dissolved in 15 cc. chloroform, and 25 to 50 cc. of Hübl's iodine solution (made by mixing solutions of 25 grm. iodine in 500 cc. 90 per cent. alcohol, and 30 grm. $HgCl_2$ in 500 cc. alcohol) added. After allowing to stand for 24 hours in a stoppered bottle out of contact with light, 15 to 20 cc. KI solution are added, to prevent precipitation of mercuric iodide, and the solution titrated with sodium thiosulphate solution (24 grm. per litre) until it is pale yellow. Water and starch solution are added, and the titration completed. The thiosulphate solution is standardised against the iodine solution, and also against a solution of 3·874 grm. $K_2Cr_2O_7$ in 1 litre, of which 1 cc. corresponds to 0·01 grm. free iodine. (10 cc. 10 per cent. potassium iodide solution, 5 cc. concentrated hydrochloric acid, and 20 cc. potassium dichromate solution are allowed to stand for 15 minutes and then titrated with thiosulphate,

using starch solution as indicator.) From these values the Iodine value may be calculated.

Hanus method. 0·15 to 1·0 grm. of the fat, according to its nature (see Hubl's method), is weighed into a small glass tube, which is transferred to a 350 cc. bottle with a well-ground stopper. The oil is dissolved in 10 cc. chloroform, 20 cc. Hanus solution added, and the whole allowed to stand for one hour, with occasional shaking. 20 cc. of a 10 per cent. solution of potassium iodide and 150 cc. water are added, and the iodine liberated titrated with N/10 sodium thiosulphate solution. A blank test on the chloroform and Hanus solution is performed at the same time. The iodine value is calculated from the difference between the amounts of thiosulphate solution required by the blank and the test.

The Hanus solution is prepared by dissolving 13·2 grm. iodine in 1,000 cc. glacial acetic acid, and adding 3 cc. bromine. The acetic acid used should not give a green colour when mixed with a few cc.'s of a solution of chromic acid in concentrated sulphuric acid.

Wijs' method. 0·15 to 1 grm. of the fat (see Hubl's method) is weighed off and introduced into a litre bottle provided with a ground-glass stopper. The fat is dissolved in 10 cc. of carbon tetrachloride, 25 cc. of the Wijs' solution added, and the mixture allowed to stand in the dark: half-an-hour for non-drying oils, one hour for semi-drying oils, or two hours for drying oils. If the deep brown colour of the solution disappears, a further 25 cc. of the Wijs' solution is added. After standing for the requisite amount of time, 15 to 20 cc. of a 10 per cent. solution of potassium iodide and 500 cc. of water are added. If a red precipitate of mercuric iodide is obtained at this point, further potassium iodide solution must be added. The free iodine is then titrated with standard thiosulphate. A blank is carried out to determine the exact strength of the Wijs' solution, and the iodine value is calculated upon the difference between blank and test as before.

Wijs' solution is prepared by dissolving 9·4 grm. of iodine trichloride and 7·2 grm. of iodine separately in glacial acetic acid on the water-bath, care being taken that no moisture is absorbed during the process of solution. The two solutions are poured into a litre flask, and made up to the mark with glacial acetic acid. The glacial acetic acid, and also the carbon tetrachloride used in the test, must be tested for oxidisable impurities by means of chromic acid and concentrated sulphuric acid; they should not change to a green colour even on prolonged standing.

A cheaper and more convenient laboratory method of preparing Wijs' solution consists in dissolving 13 grm. of iodine in a small amount of glacial acetic acid and determining exactly the iodine present by titration with standard thio sulphate. Washed and dried chlorine gas is then passed into the solution until the titration with thiosulphate is exactly doubled. (A small quantity of the original solution may be held back for addition in case the passage of the chlorine has been continued too long.) A very pronounced change in colour takes place when the titration is doubled, and hence the point at which all the iodine is converted into iodine monochloride is easily ascertained.

3. The *Hehner value* is the percentage of water-insoluble fatty acids and unsaponifiable matter in a fat. 3 grm. of the fat are saponified with 50 cc. alcohol and 2 grm. KOH in a porcelain dish on the water-bath, the solution evaporated to dryness, and the residue dissolved in 100 cc. hot water. The insoluble fatty acids are liberated by addition of 5 cc. conc. H_2SO_4, melted, and transferred to a weighed filter. They are washed with hot water, solidified, dried and weighed. (Butter fat contains 87.5 per cent., and vegetable fat 95.5 per cent. insoluble fatty acids. If, for example, 91 per cent. insoluble fatty acids is found, the percentage of added fat (x) is found as follows :

$95.5 - 87.5 = 8$; $91 - 87.5 = 3.5$; and $8 : 3.5 = 100 : x$.)

4. *Volatile fatty acids*. The Reichert-Meissl number is the number of cc. of $N/10$ alkali required for neutralisation of the volatile fatty acids distilled from 5 grm. of the fat.

5 grm. of the fat are gently warmed with 20 grm. glycerin and 2 cc. caustic soda (100 parts NaOH in 100 parts water). When the frothing has subsided, and the mixture becomes quite clear, the saponification is complete. The solution is cooled to 90°C., and 90 grm. hot water, and 50 cc. dilute sulphuric acid (25 cc. H_2SO_4 per litre) are added. The flask in which the experiment is carried out is connected by means of a bent bulb-tube to a condenser, 110 cc. are distilled over, filtered, and 100 cc. of the filtrate withdrawn by means of a pipette. This is titrated with $N/10$ alkali, using phenolphthalein as indicator. The number of cc. found is multiplied by 1.1, which gives the true Reichert-Meissl number.

5. *Maumené test* (Archbutt's modification). 50 grm. of the oil are placed in a 200 cc. beaker, and placed, together with a bottle of concentrated sulphuric acid, in a large vessel of water until both liquids have acquired the same temperature, which should be about 20°C. The beaker containing the oil is then removed, wiped on the outside, and transferred to a

cardboard box lined with cotton wool. A thermometer is immersed in the oil, the temperature noted, and 10 cc. of the concentrated sulphuric acid are withdrawn from the bottle by means of a pipette, and run into the oil, the time for emptying the pipette being one minute. The oil is stirred until no further rise in temperature takes place, when the rise in degrees Centigrade is taken as the Maumené number. The apparatus used must be a standard one, and the acid always of the same strength, so that the results obtained may be comparative.

VARIABLES OF OILS AND FATS.

1. The *Acid value* is the number of milligrams of KOH required to neutralise the free acid in 1 grm. of a fat. 2 grm. of fat are dissolved in 50 cc. alcohol or ether-alcohol mixture, a few drops of phenolphthalein added, and titrated with $N/2$ caustic alkali. For oils containing very small amounts of free acid, 5 to 10 grm. are dissolved in ether or petroleum ether, an equal volume of alcohol added, and titrated with $N/10$ alkali.

The free acid may also be calculated as percentage of oleic acid in the original fat (1 cc. N. alkali = 0·282 grm. oleic acid).

2. The *Ester value* is the number of milligrams of KOH required to saponify the neutral esters in 1 grm. of fat, and is the difference between the saponification and acid values. From this the glycerin content may be ascertained, as in the saponification of neutral esters 1 grm. of caustic potash liberates 0·5476 grm. glycerin.

For dark-coloured fats, the free acids are neutralised with sodium carbonate (1·5 grm. Na_2CO_3 in 50 cc. of 50 per cent. alcohol), 50 cc. $N/2$ alkali are added, and the saponification conducted on the water-bath as before. The baryta soap, colouring matter, and carbonate are precipitated by means of 150 cc. of a 5 per cent. $BaCl_2$ solution, and the clear solution titrated with oxalic acid.

3. The *Acetyl value* shows the amount of oxyacids present in the fat, represented by the number of milligrams of KOH necessary to saponify 1 grm. of the acetylated oil. 10 cc. of the oil are mixed with 10 cc. of acetic anhydride and 1 to 2 grm. of recently fused, anhydrous sodium acetate, and boiled on a sandbath for two hours under a reflux condenser. The mixture is cooled, water is added, and the mixture heated for half-an-hour. The acetylated oil is transferred to a separating funnel, washed with dilute caustic soda, and then with water

until neutral. The acetylated oil is dried over anhydrous sodium sulphate, and then about 2 grm. are saponified with alcoholic caustic potash as described under "Saponification value," the result being calculated in the same manner.

ADULTERATION OF FATS.

The determination of the refractivity and the other constants gives an indication of the adulteration of fats. The following reactions serve to identify certain fats:

1. *Phytosterol.* 50 grm. fat are saponified with 95 cc. of 15 per cent. alcoholic potash on the water-bath. The powdered soap is extracted with ether in a separating funnel, the tap of which is packed with cotton wool. In about an hour the unsaponifiable matter, particularly phytosterol and cholesterol, passes into ether solution, which is separated and evaporated. The residue is saponified with 5 cc. alcoholic potash, and the soap extracted again with ether. The residue from the ether solution is extracted with hot alcohol. Cholesterol or phytosterol crystals (thin plates or clusters of needles) are deposited from the alcohol solution, and these are purified by repeated solution in ether, and recrystallisation from alcohol. The crystals are identified by examination in polarised light, or by the melting point of the acetate obtained as follows:

The crystals are heated in a thin glass vessel with 2 to 3 cc. acetic anhydride, and the ester produced dissolved in 25 cc. absolute alcohol. The crystals slowly precipitated from this solution are recrystallised, and the melting point ascertained. The true melting point is obtained by means of the usual formulæ. Melting point of cholesterol acetate is 114·6° (corr.). If the M.P. is over 119°, it corresponds to phytosterol, which is present only in vegetable fats.

2. *Detection of Vegetable oils in Animal fats.* 1 grm. of the molten, filtered fat (*e.g.* lard) is dissolved in 5 cc. chloroform, and shaken with 2 cc. phosphomolybdic acid solution (sodium salt + HNO_3). In absence of vegetable oils the mixture is yellow; in their presence it is green, and the aqueous layer is light green, turned blue by ammonia. This is not quite reliable, as fish oils behave as vegetable oils.

3. *Detection of Cotton Seed Oil.* 2 cc. of oil are heated in a brine-bath with an equal volume of amyl alcohol and carbon disulphide in which 1 per cent. of sulphur is dissolved, when, in presence of cotton seed oil, a magenta coloration is obtained.

4. *Detection of Oil of Sesame.* To 0·1 cc. of a solution of 2 grm. furfural in 100 cc. alcohol, 5 cc. of molten fat (or 10 cc oil) and 10 cc. hydrochloric acid (Sp. Gr. 1·19) are added, and the mixture shaken for half a minute, and allowed to settle. The bottom layer is coloured carmine in presence of Sesame oil.

5. *Detection of Arachis Oil.* Arachidic acid (M.P. 75°) is separated from the fatty acids by recrystallisation from alcohol.

6. *Detection of Turpentine.* This is effected in the polarimeter, using an oil diluted with petroleum ether. In a 200 mm. tube it causes a dextro-rotation of about 30°. Animal and vegetable oils only give ± 1°.

7. *Detection of Resin.* (See Resin soaps, later.)

8. *Detection of Mineral Oil.* Fluorescence ("bloom") may be observed. The unsaponifiable matter (in pure fats 0·5 to 1·5 per cent.) is abnormally high.

9. *Detection of Fish oils.* About 1 grm. of the fatty acids of the oil is dissolved in 40 cc. of ether, 5 cc. of glacial acetic acid added, and the mixture cooled to 0°C. in ice. Bromine is then added until the red colour persists in the solution. The mixture is allowed to stand at 0°C. for about 15 minutes, when the formation of a white precipitate (the bromine addition compound of the unsaturated fatty acids) indicates the presence of fish oils. The test may be made quantitative if the precipitate is carefully filtered off through a tared Gooch crucible.

Hydrogenated fish oils may not give this reaction, as the fatty acids may have been saturated by the hydrogenating process.

Soap Analysis.

1. *Water.* 5 to 8 grm. of the clean soap are dried at 100° to 105°C. until the weight becomes constant. Soaps containing a large amount of water, and which melt about 100° are mixed with pumice-stone or sand. The presence of liquid hydrocarbons causes incorrect values in the direct determination.

2. *Total fat*, including fatty and resin acids, neutral fat and unsaponifiable.

10 grm. soap are dissolved in hot water, and decomposed in a separating funnel with dilute sulphuric acid. The fatty acids are shaken with 100 cc. petroleum ether (B.P. below 65°C.), and the water layer is run off into a second separating

funnel and again extracted with 100 cc. petroleum ether. The extracts are distilled on a water-bath (70°) and the residue dried, for cocoanut and palm kernel fatty acids not over 55°, and for linseed oil fatty acids in a sulphuric acid dessicator.

Another method necessitates the use of a burette of 200 to 250 cc. capacity, rounded at the bottom, and closed at the top by means of a tap. 10 grm. of the soap are dissolved in 50 cc. of a mixture of methylated spirit and water (1 : 1), and transferred to the burette, which contains an excess of hydrochloric acid. The burette is filled to the 100 cc. mark with water, and the soap decomposed by vigorous shaking. The volume is made up to 200 cc. with ether, the whole shaken, and allowed to stand. An aliquot portion, say 25 cc., of the ether is withdrawn, evaporated, and the residue weighed.

A further method consists in dissolving 20 grm. of the soap in water in an evaporating basin, decomposing with 10 to 15 cc. hydrochloric acid, and boiling until the fatty acids, etc., form a clear layer on top. 6 grm. of beeswax (or a mixture of 3 parts beeswax and 1 part paraffin wax) are added, and allowed to melt and mix with the fatty acids. The whole is cooled, and the cake of wax transferred to a tared crucible, in which it is dried, and finally weighed. The weight of beeswax is subtracted, and the percentage of total fat calculated on the remainder.

3. *Unsaponifiable matter* is determined as for oils and fats. Cocoanut oil and palm kernel oil soaps are cleaned and dried, and then extracted directly with ether to extract the unsaponifiable matter.

4. *Free fatty acids.* 20 grm. soap are dissolved in 60 per cent. alcohol and titrated with N/10 alcoholic potash :

$$1 \text{ cc. N/10 alkali} = 0.0282 \text{ grm. oleic acid.}$$

5. *Unsaponified fat.* 6 to 8 grm. of the total fat from (2) are dissolved in 96 per cent. alcohol and made slightly alkaline with N/2 alkali, using phenolphthalein as indicator. This is extracted with ether, and the residue on evaporation is unsaponified fat *plus* unsaponifiable matter. This is saponified with an excess of alcoholic potash. On extracting again with ether the unsaponifiable matter is obtained, and is subtracted from the residue from the first extraction to give unsaponified fat.

6. *Resin.* For detection of resin acids, the total fat obtained from (2) is boiled with acetic anhydride. After cooling, one or two drops of sulphuric acid (Sp. Gr. 1·53) are added. A transitory magenta coloration shows the presence of resin acids. A similar reaction is shown by cholesterol (*e.g.* wool fat).

For determination, 2 to 3 grm. are mixed with 10 times the amount of absolute alcohol. After cooling, dry HCl gas is bubbled through the solution, until no more absorption takes place (about $\frac{3}{4}$-hour is necessary). After standing for one hour, it is diluted with 5 times the amount of water, and shaken in a separating funnel with 75 cc. ether. The ether layer (containing ethyl esters of the fatty acids + resin acids) is withdrawn, washed, 50 cc. alcohol added, and titrated with N/2 alkali.

$$1 \text{ cc.} = 0\cdot175 \text{ grm. resin acids.}$$

7. *Total alkali.* 10 grm. of the soap are decomposed with 50 (or if necessary 100) cc. of N. H_2SO_4 in an evaporating dish. The solution is boiled until the fatty acids are clear, when it is allowed to cool, and the aqueous layer titrated with alkali. If the fatty acids do not solidify, 15 grm. wax (preferably beeswax) or stearin are added before the solution is cooled.

8. *Free alkali.* 10 grm. of the soap are dissolved in 100 cc. absolute alcohol, and titrated with N/10 HCl, using phenolphthalein as indicator.

For determining small amounts of free alkali, the soap is dissolved in water, and precipitated hot with barium chloride solution (30 : 100), and the filtrate from the barium soap is titrated with N/10 acid.

9. *Combined alkali.* The alcohol insoluble from (8) is dissolved in water and titrated. Alternatively, carbon dioxide is passed through an alcoholic solution of 10 grm. of the soap, until all free alkali is converted into carbonate. The solution is filtered, the precipitate washed with hot alcohol, dissolved in water, and titrated with N/10 HCl. using methyl orange as indicator.

Silicate and borate are estimated as carbonate by this method.

10. *Glycerin.* 5 grm. soap are dissolved in hot water, and decomposed with sulphuric acid on the water-bath. The solution is then filtered through a wet filter-paper and precipitated with basic lead acetate. It is diluted to 250 cc., and the glycerin determined in an aliquot portion (see under " Glycerin ").

11. *Water softening power.* 2·5 grm. of the soap are dissolved in a mixture of alcohol and water, and the solution made up to 250 cc. This solution is then run from a burette into 10 cc. of X_{10} Clark's hardness solution and 90 cc. of distilled water until the foam obtained by vigorous shaking shows no inclination to break after one minute. The reading (A) of the burette is then taken and the water softening

power (x) calculated as percentage from the following formula :—

$$x = \frac{2800}{A}$$

The X_{10} Clark's hardness solution is made by dissolving 2·287 grm. of calcium carbonate in as small an amount of dilute hydrochloric acid as possible, boiling to expel carbon dioxide, neutralising with dilute ammonia, and making up to a litre with distilled water

12. *Foreign matter*.

(*a*) The alcohol insoluble is determined by extraction with 98 per cent. alcohol in a weighed and dried (at 105°) filter thimble.

(*b*) Inorganic matter. About 5 grm. soap are carefully carbonised in a weighed platinum capsule. The carbonised residue is powdered, digested with water, and filtered through an acid-extracted filter. The residue is dried in the capsule, and burnt completely to ash. The filtrate is evaporated in the same capsule, and finally taken to dryness with addition of a small amount of ammonium nitrate, ignited, and weighed.

For estimation of silicate, the ash is decomposed with HCl and dried. It is then reheated with conc. HCl. It is taken up with hot dilute HCl, filtered, and the filter-paper burnt in a platinum capsule, which is ignited and weighed.

(*c*) Organic substances. The amount of alcohol-insoluble organic matter is the difference between (*a*) and (*b*).

Starch. The saponified fatty acids from 5 to 10 grms. soap are extracted with 60 to 80 cc. 2 per cent. alcoholic potash, in which starch is insoluble. The residue and filter are digested with 60 cc. 6 per cent. aqueous KOH; the liquor is made acid with acetic acid, diluted to 100 cc. in a measuring cylinder with water, and filtered through cotton wool. 25 or 50 cc. of the filtrate are taken, and to this are added 2 drops acetic acid and 30 or 60 cc. 96 per cent. alcohol. On standing, a precipitate is formed, which is filtered off through a weighed filter, washed with 50 per cent., and then with absolute alcohol, finally with ether, and then dried and weighed.

Dextrin. This is extracted from the alcohol-insoluble by means of cold water and precipitated by alcohol.

Sugar. This is determined by means of the inversion polarimeter, or by means of Fehling's solution.

Alcohol. This is determined by means of the pyknometer in the distillate from the acid solution produced by the decomposition of the soap solution with H_2SO_4.

Liquid hydrocarbons and ethereal oils are distilled from a solution of 30 to 40 grm. of soap in 150 cc. water, decomposed with dilute H_2SO_4, and are collected in a calibrated burette.

(d) Oxygen agents (Sodium peroxide, perborate, percarbonate, persulphate).

Detection : 2 grm. of the substance are shaken successively with water, dilute sulphuric acid, and 2 cc. of chloroform. Hydrogen peroxide may be detected in the aqueous layer by the perchromic acid or titanic acid test.

The method of determining the oxygen by means of N/10 permanganate is stated to be incorrect by Bosshard and Zwicky, who use the gasimetric method, liberating the available oxygen by means of manganese dioxide. The most convenient is the method suggested by Farrar, in which ferrous ammonium sulphate is oxidised, and the ferric salt formed determined by titration with titanous chloride.

Glycerin.

I. *Chemically Pure Glycerin*

(a) *Specific Gravity* should be 1·24 to 1·26.

(b) *Colour* in a tintometer.

(c) *Ash* should be practically nil.

(d) *Impurities* usually tested for are sugar (by Fehling's solution), arsenic (by zinc, hydrochloric acid and mercuric chloride paper), chloride, sulphate, heavy metals (with hydrogen sulphide), butyric acid (by alcohol and sulphuric acid), and organic matter (by strong sulphuric acid).

II. *Dynamite Glycerin.*

(a) This should be free from chloride, sulphate, calcium, magnesium, aluminium, and arsenic. 1 cc. should give no opalescence when mixed with 2 cc. water and 2 drops silver nitrate solution.

(b) Specific gravity at 15°C. should be 1·261 to 1·263.

(c) It should contain no free acid nor any quantity of reducing matter. Total insoluble should be very low. No turbidity should be caused by higher fatty acids, on addition of an equal volume of hydrochloric acid to 1 part glycerin in 2 parts water. There should be no precipitation of silver on addition of 3 drops of 10% silver nitrate. The total insoluble matter, when 5 grm. of the glycerin are heated to 160° to 180°C. until constant in weight, should not be above 0·25%.

(d) The product of nitration must be very pale, and separate easily.

About 20 grm. of glycerin is run from a burette into a weighed beaker, and its weight determined. A water-cooled beaker, containing 150 grm. "mixed acid" (1 part commercial HNO_3 of Sp. Gr. 1·5, and 2 parts H_2SO_4 of Sp. Gr. 1·845) is brought under the burette, and glycerin is carefully run into this, stirring with a thermometer. The temperature must not rise above 25°C., and fresh glycerin must only be run in when the temperature has fallen to 12 or 13°C. When an amount of glycerin, equal in volume to the quantity first withdrawn from the burette and weighed, has been run into the acid, the contents of the beaker are poured into a measuring cylinder, and the separation observed.

The number of cc. of the upper layer, multiplied by the specific gravity of nitroglycerin (1·6009 at 15°) gives the weight of nitroglycerin, which should not be under 200 per cent. of original glycerin used (usual figure 207–210 per cent.). The difference between this and the theoretical 246·7 per cent. shows the nitroglycerin dissolved in the "mixed acid."

III. *Crude Glycerin.*
(International Standard Methods, 1911.)

(a) *Free caustic alkali.* 20 grm. sample are diluted to 100 cc., together with an excess of neutral barium chloride solution and 1 cc. phenolphthalein solution. The precipitate is allowed to settle and 50 cc. of the clear liquid titrated with normal acid. Free caustic alkali is calculated as Na_2O.

(b) *Ash and total alkalinity.* 2 to 5 grm. sample are thoroughly charred in a platinum dish over a very small flame; the mass is extracted with hot water, filtered, and the residue ignited in the dish. The filtrate and washings are then returned to the dish, evaporated, and ignited without fusion. The ash is weighed, dissolved, and titrated with normal acid for total alkalinity, calculated as Na_2O.

(c) *Alkali present as carbonate.* 10 grm. sample are diluted with 50 cc. of distilled water and sufficient normal acid to neutralise the alkalinity found in (b). The solution is boiled under a reflux for 15 to 20 min., the condenser tube washed down into the flask, and the solution and washings titrated with normal caustic soda, using phenolphthalein as indicator. This figure is calculated to Na_2O, from which is subtracted that found in (a), the difference being Na_2O present as carbonate.

(d) *Alkali combined with organic acids.* The sum of the percentages of Na_2O found in (a) and (c) deducted from that found in (e) represents the Na_2O or other alkali combined with organic acids.

X

(e) *Acidity.* 10 grm. sample diluted with 50 cc. distilled water are titrated with normal caustic soda, using phenolphthalein as indicator. The result is expressed in terms of Na_2O to neutralise 100 grm.

(f) *Total residue at 160°C.* 10 grm. sample, together with sufficient normal hydrochloric acid or sodium carbonate to cause the glycerin to have an alkalinity not exceeding 0·2% sodium carbonate, are made up to 100 cc., and 10 cc. measured into a tared flat-bottomed dish. This is placed on top of the air oven, until most of the water has evaporated. The dish is then transferred to the interior of the oven, the door of which is left open so that most of the glycerin is evaporated at 130°—140°C. The dish is then allowed to cool, and the residue taken up with 0·5–1·0 cc. water. This is evaporated on top of the oven, and the dish heated in the oven at 160°C. for one hour, cooled and weighed. The process of treating with water, evaporating, heating for one hour, cooling and weighing, is repeated until a constant loss of 1 to 1·5 mgrm. per hour is obtained. The weight is corrected for the amount of hydrochloric acid or sodium carbonate added, and the result multiplied by 100 to give the percentage of total residue at 160°C.

(g) *Organic residue at 160°C.* The ash is subtracted from the result found in (f), the difference being expressed as organic residue at 160°C.

(h) *Moisture.* 1 to 1·5 grm. sample are dried on a weighed quantity of pure bulky asbestos in a vacuum dessicator containing sulphuric acid.

(i) *Glycerin.*

(i) Acetin method. 1·25 to 1·5 grm. sample are weighed into a 120 cc. flask, connected to a reflux condenser by means of a ground glass joint. The glycerin is then boiled for one hour with 7·5 cc. of pure acetic anhydride and 3 grm. of pure, recently fused sodium acetate. This mass is allowed to cool, 50 cc. water added down the condenser, and warmed to 80°C. until solution is complete. The solution is filtered into a litre flask and the acetylating flask and filter paper well washed. 2 cc. of 0·5% phenolphthalein solution are added and the solution exactly neutralised. 50 cc. normal caustic soda are added, and the solution gently boiled under a reflux air condenser for 15 mins. It is then quickly cooled and titrated with normal acid. From the amount of caustic soda used the percentage of glycerin may be calculated, after making a correction for a blank test done on 7·5 cc. of acetic anhydride and 3 grm. of sodium acetate.

1 cc. N. NaOH = 0·03069 grm. glycerin.

A further correction may be made if the organic residue at 160°C. is high, by acetylising the organic residue and proceeding as above. The result is calculated to glycerin and subtracted from the above.

(ii) Dichromate process. 20 grm. glycerin are diluted to 250 cc., 20 cc. taken, and a small amount of silver carbonate (freshly precipitated from 140 cc. of 0·5% silver sulphate solution by means of about 4·9 cc. normal sodium carbonate solution) added. The solution is allowed to stand, with occasional agitation for 10 mins., when a slight excess of basic lead acetate solution is added. The mixture is allowed to stand a few moments, and is made up to 100 cc., an extra 0·15 cc. being allowed for the volume of the precipitate. The whole is then thoroughly mixed and filtered. 25 cc. of the clear filtrate are taken, 12 drops of pure sulphuric acid (1 : 4), and then 3·7282 grm. pure powdered potassium dichromate added. This is rinsed down with 25 cc. water, the dichromate is allowed to dissolve, and 50 cc. of sulphuric acid (1 : 1) added. The solution is kept in a boiling water-bath for 2 hours, a weighed excess of ferrous ammonium sulphate added, and the excess titrated with dilute potassium dichromate solution, using potassium ferricyanide as outside indicator. The glycerin is calculated from the amount of dichromate reduced.

1 grm. glycerin = 7·4564 grm. dichromate.
1 grm. dichromate = 0·13411 grm. glycerin.

IV. *Soap Lyes.*

The glycerin in soap lyes may be estimated by boiling down a quantity of the lye and carrying out an acetin test on the residue, or by a dichromate test on the lye itself. The former is the more accurate method, but the latter is more rapid and more suitable for works practice.

5 cc. of the soap lye are neutralised with semi-normal hydrochloric acid, and the soap precipitated by basic lead acetate (the necessary quantities may be determined on a separate quantity of 5 cc.). The solution is then made up to 250 cc., allowing 0·25 cc. for the volume of the precipitate. The mixture is thoroughly shaken, and then filtered. 50 cc. of the clear filtrate are taken, a few drops of 1 : 4 sulphuric acid added to precipitate any slight excess of lead, and then an excess of fairly strong potassium dichromate and 50 cc. of sulphuric acid (1 : 1) added. The solution is heated in a boiling water bath for two hours and then titrated back with ferrous ammonium sulphate solution. The percentage of glycerin is calculated from the amount of dichromate reduced, as for pure glycerin determinations.

OILS, FATS, AND WAXES.

Name and Source.	Sp. Gr. at 15·5°. Oils, &c.	Fatty acids.	Refractive index. Oils at 15°C., &c.	Fatty acids at 60°C.	Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C. Oils, &c.	Fatty acids.	% Insoluble fatty acids and unsaponifiable matter.
1 Almond oil *Prunus amygdalus*	0·9178—0·9172	…	1·4728	1·4461	−10 to −21	9·5—10·1	…	13—14	96·2
2 Apricot kernel oil *Prunus armeniaca*	0·9172—0·920	0·9195	1·4712 (20°)	…	−20	…	…	2·3—4·5	95·40
3 Arachis oil *Arachis hypogaea*	0·91795	0·8460 (99°)	1·4731	1·4461	0 to +2	28·1—32	…	31—32	94·8—95·3
4 Beechnut oil *Fagus sylvatica*	0·9205—0·9225	…	…	…	−17	17	…	23—24	95·16
5 Ben oil *Moringa pterygosperma* (15°)	0·912—0·920	…	…	…	8·8	37·2—37·8	…	…	…
6 Be3 tallow	0·913—0·952 (15°)	0·8698 (100°)	1·4510 (60°)	1·4398—1·4451 (75°)	35—27	43·5—44·5	43—47·6	43—46	95·4—9;
7 Beeswax *Apis mellifica*	0·962—0·975 (15°)	…	…	…	60·2—62·5	…	62·5—63·6	67·2	…
8 Bone fat	0·914—0·916	0·907—0·914 (37·75°)	1·459—1·462 (25°)	1·437—1·439	15—17	28	21—22	30	90—97
9 Butter fat	0·936—0·940 (15°)	…	…	…	19·1—24·5	35·8—38	28·4—33·3	38—43	86·45—90·8
10 Cacao butter *Theobroma cacao*	0·964—0·976	0·91357	1·4496 (60°)	1·422	23—26	48·3—49·6	28·5—33·6	48—52	94·59
11 Candelilla wax *Pedilanthus pavonis*	0·936—0·993	…	1·4555 (71·5°)	…	63·8—68	…	66—68·4	…	…
12 Carnauba wax *Copernica cerifera* (15·)	0·990—0·999	…	…	…	80—87	…	83—86	…	…
13 Castor oil *Ricinus communis*	0·9591	0·9509	1·4795—1·4808	1·4546	−10 to −12	3	…	13	…

	Unsaponifiable matter.	Saponification value mgrms. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Fatty acids.	Maumené's Test, 0°C.	Reichert-Meissl value cc. $\frac{N}{10}$ KOH.	Mean mol.-wt. of fatty acids.	Acid value.	Other data.
1	...	189·5—195·4	204	93·0—100·2	93·5—96·5	51—53	...	275	0·7—5·6	White elaidin.
2	...	190·3—198·2	197	101—108·7	102·6—103·8	42·5	...	288·6	0·64	
3	0·54—0·94	189·3—196	201·6	83·3—105	95·5—96·9	46—51	...	281·8	1·2—32	
4	...	191·1—196·3	...	111·1—120·1	114	63—65	...	...	...	
5	1·67—2·69	184·6—187·7	...	72·88 & 110—112	...	...	...	...	...	
6	...	193·2—198	197·2—201·6	35·4—47·5 & 41·3	25·9—32·8	...	0 25	270—286	3·5—50	
7	52·4—55·6	90·1—98·9	...	7·9—11	...	...	0·34—0·54	...	17—22	Acetyl value 15·24.
8	0·5—1·8	191—195	200—220	46·3—49·6	55·7—57·4	...	...	275	210—211·4	Ash 1·25—2·40%. Water 11·6%. Heat of Bromination 6·6—7·0 & 9·5
9	0·31—0·42	219·7—232·6	210—220	25·7—37·9	28—31	...	20—63 & —33·15	263	0·4—35	
10	1·75—3·08	191·8—202	190	34·3—37	32·6—39·1	...	0·3—0·5	295	1—2·8	
11	65—77	46·8—64·9	...	14—20	...	...	...	...	12·4 —21·18	Sol. in turpentine, chloroform, and carbon tetrachloride.
12	54·8—55	79—88·3	...	13·2—13·5	...	...	...	...	2—7	
13	0·30—0·57	176·7—186·6	...	81·4—90·6	86—88·3	46—47	1·1	295	0·3—4	Acetyl value 150, Rot. 200 mm. 7·5° to 10°. Opt.

OILS, FATS, AND WAXES—continued.

Name and Source.	Sp. Gr. at 15·5°. Oils, &c.	Sp. Gr. at 15·5°. Fatty acids.	Refractive index. Oils at 15°C., &c.	Refractive index. Fatty acids at 60°C.	Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C. Oils, &c.	Melting Pt. °C. Fatty acids.	% insoluble fatty acids and unsaponifiable matter.
14 Chaulmoogra oil *Taraktogenos Kurzii*	0·951—0·952 (25°)	...	1·4777 (25°)	...	...	39·6	...	44—45	...
15 Chinese Tung oil *Aleurites cordata*	0·940—0·943	...	1·521—1·523	...	2—3	37·1—37·2	...	40·3—43·8	95·0
16 Chinese vegetable tallow *Stillingia sebifera*	0·890 & 0·915—0·918 (15°)	...			24·2—35	52·1—53·5 & 40—48	43—46	53—56·9	93·45—95·7
17 Chinese wax (or insect wax) *Coccus ceriferus*	0·970 (15°)	...			80·5—81	...	80·5—83	92·2	51·54
18 Clover oil *Trifolium*	...	...			14—23	21·2—25·2	...	...	R=red 93·62 W=white 93·24
19 Cocoa nut oil *Cocos nucifera*	0·9250	0·8854 (98—99°) (water 15·5=1)	1·441(60°)	1·4295		23·5—26·4	...	24—27	88·6—90·5
20 Cod liver oil *Gadus morrhua*	0·9224—0·930	...	1·4800—1·4852		0 to −10	13·3—24·3	...	...	95·3—96·5
21 Corn oil, see Maize oil.									
22 Cotton seed oil *Gossypium herbaceum*	0·9250	0·92055—0·9210 (15·5/4)	1·4743—1·4752		3—4 below 12° stearine separates	33·3—37·6	...	34—38	95·96
23 Cotton seed wax or Cotton seed stearin *Gossypium herbaceum*	0·91884 (15°)	...			16—22	34·9—40·8	28—40	27—30	95·5—96·3
24 Croton oil *Croton Tiglium*	0·9375—0·9428	...	1·4781 (26°)	...	−7	18·6—19	...	...	88·9—89·1

	Unsaponifiable matter.	Saponification value mgrns. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Iodine value % Fatty acids.	Maumené's Test, 0°C.	Reichert-Meissl value cc. $\frac{N}{10}$ KOH.	Mean mol. wt. of fatty acids.	Acid value.	Other data.
14	...	200·3—213	215	103·2—104·4	103·2	...	...	...	9·5—56	Sp. Rot. [a]15° 52 to 51·3.
15	0·44	190—197	188·8	150—176·2 (Hubl), up to 210 (Hanus).	145·4—159·4	...	...	...	0—12	Polymerised to jelly at 250°.
16	...	200·3—205·7	202—208·5	32·1—32·3 & 28—37	30—55	...	0·69	...	2·2—14·2	
17	...	80·5—93	...	1·4	...	...	...	...	1·4—1·5	Alcohols 49·5%
18	For R.= For W.=	189·9 189·5	198·1 197·6	124·3 119·7	126·2 122·2	...	3·3 3·5	283·2 283·8	...	
19	0·179—0·297	251—268·4	258	8—10	8·39—9·3	...	6·55—8·0	196—204	5—50	
20	0·54—7·83	179—193·4	204·4—207	135—172·6	164—171	100·2—116	0·4—0·76 (Reichert)	...	0·25—3	Sp. temperature reaction 243—272.
21 22	0·73—1·64	191—193·8	201·6—203·9	101—120	105—115	75—76 & 80—90	...	275	Below 2 (best)	Heat of bromination 19·4, Sp. T.° reaction 169—170
23 24	0·22	195 ... 210·3—215·6	201	90—103 101·7—109·1	94 111·2—111·8	...	12·1—13·6	...	19—32 27·3 (expressed oil)	

OILS, FATS, AND WAXES—*continued*.

Name and Source.	Sp. Gr. at 15·5°		Refractive index.		Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C.		% Insoluble fatty acids and unsaponifiable matter.
	Oils, &c.	Fatty acids	Oils at 15°C, &c.	Fatty acids at 60°C.			Oils, &c.	Fatty acids.	
25 Curkas oil or Purging nut oil *Jatropha curcas*	0·9204	...	1·4681—1·487(25°)	...	...	...	−4	24—26	95·5
26 Ceresin *Ozokerite paraffin*	0·9170 (20°) 0·918—0·922 (15°)	...	...	...	61—63	...	64—65 & 61—78	...	...
27 Dika fat or oil *Irvingia gabonensis*	0·863 (100°, water at 15°=1)	...	1·4505 (50°)	1·4357 (50°)	27·2—29·4 & 39·2—39·9	34·8—38·1	38·9—41·3	40·8	94·38
28 Dolphin oil (body) *Delphinus globiceps*	0·9266 (15°)	...	1·4708	...	5 to −3 deposits spermaceti.	...	...	...	...
29 Earthnut oil, see Arachis oil.									
30 Goose fat *Anser cinereus*	0·922—0·9300(15°)	0·9257(15°)	...	...	18—20	31—34	27·5—34	36·6—41	92·4—95·88
31 Grape seed oil *Vitis vinifera*	0·9202	...	1·4713 (25°)	...	−11 to −17	18—20	...	23—26	92·13—97·6
32 Gynocardia oil *Gynocardia odorata*	0·925—0·927 (25°)	...	...	...	...	...	...	...	...
33 Hemp seed oil *Cannabis sativa*	0·925—0·931 (15°)	...	1·447—1·496	...	Thickens at −15 and solidifies at −27	15·6—16·6	...	17—19	...
34 Herring oil *Clupea harengus*	0·9202—0·9391 (15°)	...	...	...	...	...	...	30—31·5	95·64
35 Horse fat *Equus caballus*	0·916—0·922	...	...	...	42—47	33·6—33·7	41·8—43·2	37·5—39·5	96—97·8

	Unsaponifiable matter.	Saponification value mgrms. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Iodine value % Fatty acids.	Maumené's Test, 0°C.	Reichert-Meissl value cc. N/10 KOH.	Mean mol.-wt. of fatty acids.	Acid value.	Other data.
25	...	193·2	...	98·3—100·9	105·05	65—68·3	0·55	..	0·7—8·5	Acetyl value 7·5.
26	...	...	...	...	...	...	...	...	...	Soluble in carbon disulphide (Beeswax mixed with paraffin wax).
27	...	241·2—250	254·8	3·34—5·2	14·5	...	0·42	214—218·3	3·98—6·7	
28	...	187·3—203·4	...	99·5—126·9	...	...	5·6	...	2·30—11·9	Oil has different constants if from the head.
29 30	...	191·2—198	202·4	58·7—71·5	65·1—65·3	...	0·2—0·3	...	0·7—3·5	Butyro-refractometer at 40° C. 50—50·5.
31	...	178·3—195	187·4	94—96·2 & 130—142·8	98·65—99·05 & 132·5	52—64 & 81—83	0·40—0·19 & 1·9	...	16·2	Acetyl value 23—43·7
32	...	197—199·6	199·8	152—152·8	162·6	...	...	...	4·9—5·0	Optically inactive.
33	1·08	190—193·1	...	140·5—148	141	95—98	...	...	...	
34	1—4	179—193·7	178·5	123·5—142	...	...	...	292	1·8—40·2	Bromides insol. in ether 12·7—21·7%.
35	...	195·1—197·1	202·6—202·7	71·4—86	83·9—87·1	46—54·2	1·64—2·14	...	5·9	Sp. temper. reaction 95·8—114.

OILS, FATS, AND WAXES—*continued.*

Name and Source	Sp. Gr. at 15°		Refractive index.		Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C.		% insoluble fatty acids and unsaponifiable matter.
	Oils, &c.	Fatty acids.	Oils at 15°C., &c.	Fatty acids at 60°C.			Oils, &c.	Fatty acids.	
36 Japanese fish oil *Clupanodon melanosticta*	0·9316 —0·9347	...	1·4802 —1·4808 (20°)	...	...	28·2	20—22	35·4 —36·2	94·5—95·82
37 Japanese Tung oil *Elaeococca vernicia*	0·933 —0·9400	...	1·5034 —1·5186 (25°)	...	...	33·2	...	40·3	...
38 Japan wax *Rhus succedanea*	0·975 (15°)	0·848 (98°— 99°) (water 15·5 =1)	...	...	48·5 —50·8	58·8 —59·4	50·4 —53·4	54—62	89·8—90·66
Insect wax, see Chinese wax.									
39 Illipé butter *Bassia longifolia*	·	...	1·4694	...	36	39·7—40·3	42	45	94
40 Kapok oil *Bombax Ceila and pentandrum*	0·92:5 (15°)	0·9162 (18°)	...	...	29·6	26·9—32	20—34·2	29—34·2	94·0—95·66
41 Lard oil *Sus scrofa*	0·915	...	1·4694	...	...	...	...	35	...
42 Lard *Sus scrofa*	0·934 —0·938(15°)	0·837 —0·840	1·4539(60°)	1·4395	27·1—29·9	36·0	31—48·9	43—47	95·8
43 Laurel oil *Laurus nobilis*	0·93317	...	...	...	24—25	14·3—15·1	32—36	...	83·5—86·8
44 Linseed oil *Linum usitatissimum*	0·9316 —0·9410	0·9233	1·4835	1·4546	—25 deposits stearine —10 to —15	19—20·6	—16 to —20	17—24	95·5
45 Maize oil *Zea Mays*	0·9213 —0·9274	0·8529(100°)	1·4768 (15·5°)	...	—10 to —15	19	...	18—21·6	93·57—95·7

	Unsaponifiable matter.	Saponification value mgrms. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Iodine value % Fatty acids.	Maumené Test, 0°C.	Reichert-Meissl value cc. N/10 KOH.	Mean mol. wt. of fatty acids.	Acid value.	Other data.
36	0·48—2·6	189·8 —196·2	180—189·1	180·6— 187·3 121·5 171 for commercial oils 149—158	...	...	...	281—296	10·8—34·5	Ether insoluble bromides 44·2—47·1%.
37	...	193·4— 196·3	...	...	...	...	...	262—263	...	Heat of bromination 23·1— 24·7°C.
38	1·1—1·63	220—237·5	...	4·9—15·1	...	...	...	257·6	7—33	Acetyl value 27—31·2.
39	...	187·4 —188·5	192·1	50·1—64	59·5	...	1·35	291·9	...	
40	...	189·2—205	190—202·7	118—129	108 & 122	95	...	293	1·7—20·6	
41	...	189·9—193	...	67—88	...	47	0—0·21	...	1—2	
42	0·23	195·2 —196·6	201·8 —208·6	53—76·9	64·2	24—27·5	0·49—0·77	278	0·54—1·28	
43	...	197·5 —200·9	...	66—82·3	81·6—82·0	115·6	3·2—5·4	...	...	
44	0·42—1·1	190·2 —195·2	196—198·8	170—201	179—209·8	103—145	...	283	0·8—8·4	Sp. temper. reaction 320— 349.
45	1·35—2·86	189·7—122·6	198·4	121—130·8	113—125	79—86	...	...	1·7—20·6	

OILS, FATS, AND WAXES—*continued*

Name and Source.	Sp. Gr. at 15·5°		Refractive index.		Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C.		% insoluble fatty acids and unsaponifiable matter.
	Oils, &c.	Fatty acids.	Oils at 15°C., &c.	Fatty acids at 60°C.			Oils, &c.	Fatty acids.	
46 Menhaden oil *Alosa menhaden*	0·926—0·936	...	...	...	...	...	...	...	...
47 Montan wax *Lignite wax*	...	...	...	...	...	...	80—86	...	Unsap.9·98%
48 Mustard seed oil *Sinapis nigra* (black) *Sinapis alba* (white)	0·9155 —0·9193 0·9142	...	1·4672 1·4750 (15·5°)	1·4665 (20°) 1·4630 (20°)	−15 to −16 −15 to −16·3	6—8 9—10	...	9—17 12—16	Black **95·05** —95·32 White **95·21** —96·7
49 Neat's foot oil	0·9164	0·87 9 ($\frac{100}{100}$)	1·4681(20°)	...	...	26·1—26·5	...	28·5 —29·8	95·2—**95·5**
50 Nut oil, see Walnut oil.									
51 Olive kernel oil	0·9184— 0·9193	...	1·4673— 1·4688(25°)	...	...	...	...	...	...
52 Olive oil *Olea europea sativa*	0·9155 & 0·9180 & 0·9203	0·8480 ($\frac{99}{15·5}$) 0·8749 ($\frac{100}{100}$)	1·4698	1·4410	3 to 10	16·9—26·4	...	19—29·3	94—96
53 Palm kernel oil or Palm nut oil	0·9119 ($\frac{40}{15·5}$) 0·8731 ($\frac{99}{15·5}$)	...	1·4431(60°)	1·4310	23—24	20—25·5	23—30	20·7— 28·5	91·1
54 Palm oil *Elaeis guineensis*	0·9209 —0·9245 (15)	0·8369 ($\frac{99}{15·5}$) 0·8701 ($\frac{100}{10}$)	1·4510(60°)	...	31—39	35·8—45·5	35—42	47·7—50	94·2—**97**
55 Peach kernel oil *Prunus persica*	0·9198	0·8701	...	...	Below −20	13—13·5	...	10—18·9 & 3·5	94·0

| | Unsaponifiable matter. | Saponification value mgrms. KOH for oil, &c. | Neutralisation value of fatty acids. | Iodine value % | | Maumené's Test, 0°C. | Reichert-Meissl value cc. $\frac{N}{10}$ KOH. | Mean mol.-wt. of fatty acids. | Acid value. | Other data. |
				Oils, &c.	Fatty acids.					
46	0·6—1·6	188·7—193	...	140—180	...	123—128	1·1—1·2	...	3·53—11·74	...
47	...	126·58	123·01	...	...	...	...	...	...	Not quite soluble in hot ether, soluble in CCl₄.
48	...	173·2—175·8	176·7 to 187·1	98·8—118	108·4—126·5	42—43	...	299·8—317·8	1·86—7·35	Viscosity 355—425.
49	...	170·3—177·8	181—185·8	92·1—103	94·7—110	44·15—19·5	...	301·9—310·3	...	Viscosity 402.
50 51	...	194·3—199	200·6—206·3	66—76	63·6—77	42·2—49 & 56—58	1·0	...	...	Acetyl value 22·0.
52	0·46—1·0	181·2—183·8 188·7—196	193	86—99 87·8 79—88	86·1—90·2	35—47	0·6	279·4—286	0·4—·24	Sp. temper. reaction 89—95.
53	...	242·4—250	251·7—266	10·3—17·5	12—12·07	...	5—7·6	211—222·8	8·36	
54	0·35—0·7	196·3—205·5	204—207	53—57·4	53·3	...	0·74—1·87	270—273	...	
55	...	189·1—192·5	205·0—209·9	92·5—110·1	94·1—101·9	42—43	...	278·8	2·5—6·4	Pink elaidin.

OILS, FATS, AND WAXES—*continued.*

Name and Source.	Sp. Gr. at 15·5°		Refractive index.		Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C.		% Insoluble fatty acids and unsaponifiable matter.
	Oils, &c.	Fatty acids.	Oils at 15°C., &c.	Fatty acids at 60°C.			Oils, &c.	Fatty acids.	
56 Peanut oil, see Arachis oil.									
57 Poppy seed oil *Papaver somniferum*	0·924—0·927 (15°)	0·8886 ($\frac{100}{100}$)	1·4773	1·4506	−18	15·4—16·2	...	20—21	94·97—95·88
58 Porpoise oil *Delphinus phocœna*	0·9258 (15°)	...	...	...	−16	...	...	...	91·04
59 Pumpkin seed oil *Cucurbita pepo*	0·9197	...	...	...	−16	...	...	26·5 —29·8	96·2
60 Radish seed oil *Raphanus sativus*	0·9163	...	1·471— 1·472(20°)	1·4625 —1·4630 (20°)	−10 to −17·5	S.P. 7—15	...	11—20	95·01—95·94
61 Rape oil *Brassica compestris*	0·9132 —0·9159	0·8758 ($\frac{100}{100}$) 0·8438 ($\frac{99}{15·5}$)	1·4720 —1·4757	1·4491	−10 to +10	11·7—13·6	...	18·3 —21·5	94·56—96·3
62 Sardine oil *Clupea sardinus*	0·9330 (15°)	...	...	...	...	...	...	...	95·6—97·08
63 Seal oil *Phoca vitulina* and other varieties	0·9249—0·9263(15°)	0·9156— 0·9172(15°)	1·4776	...	−2 to −3	13—17	...	14—33	92·8—95·85
64 Sesame oil *Sesamum orientale* and *indicum*	0·9203	...	1·4748 —1·4762	1·4461	−4 to −6	21·2—23·8	...	23—32	95·8
65 Shea butter *Bassia Parkii*	0·859—0·918	...	...	...	17—18	48·6—53·8	23·3—25·3	39·5 —56	94·7—96·5
66 Soya bean oil *Dolichos soja*	0·9222 —0·9279(15°)	...	1·4680 (40°)	1·465 (27·5°)	−8 to −15	21·2	...	26—29	95·5
67 Spermaceti *Physeter macrocephalus*	0·905— 0·960 (15°)	...	1·433(80°)	...	41—49	...	42—44·5	...	...

	Unsaponifiable matter.	Saponification value mgrms. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Iodine value % Fatty acids.	Maumené's Test, 0°C.	Reichert-Meissl value cc. N/10 KOH.	Mean mol.-wt. of fatty acids.	Acid value.	Other data.
56										
57	0·43	189—196·8	199	132·6—157·5	139	86—88·5	0·00	...	0·7—11	
58	3·7	195	203	88·3—119·4	...	...	47	...	5·0	
59	...	188·4—190·2	197	119·7—130·7	...	...	...	284·7	...	
60	...	173·8—181·6	182·6—189·5	92·8—112·4	97·1—115·3	51	...	...	...	Viscosity (seconds at 70° F.) 385·3.
61	0·58—1·0	170·6—178·7	185	93·5—103·6	99·8—105·6	49—60	...	307—321·2	1·4—13·2	Sp. temper. reaction 125—144.
62	0·48—1·01	...	...	161—192				285·7—299·5	4·6—24·7	
63	0·38—1·4	178—196	190·4—198	127—193	186·5—201·8		0·96—1·69	...	1·9—40	Acetyl value 16·5.
64	0·95—1·32	188·5—190·4	196—201·6	103—114·5	108·9—112	63—72	...	286	0·2—10	
65	3·5	171·8—192·3	...	56·2—67·2	55·6—57·2	...	...	...	29·4	
66	0·22	190·6—192·5	...	124—143	122	87—88	...	...	1·75—7	
67	...	120·1—134·6	...	3·8	...	...	...	...	0—1	Acetyl value 2·63.

OILS, FATS, AND WAXES—continued.

Name and Source.	Sp. Gr. at 15·5°		Refractive index.		Solidifying Pt. °C. for oils, &c.	Titer test on fatty acids °C.	Melting Pt. °C.		% Insoluble fatty acids and unsaponifiable matter.
	Oils, &c.	Fatty acids.	Oils at 15°C., &c.	Fatty acids at 60°C.			Oils, &c.	Fatty acids.	
68 Sperm oil *Physeter macrocephalus*	0·875—0·884	0·899	1·4646— 1·4655(20°)	...	...	11·1—11·9	5·5	13·3—24	60—67
69 Stag fat *Cervus elaphus*	0·9670 (15°)	0·9685 (15°)	...	...	39—48	S.P. 46—48	49—52	49·5—52	...
70 Stickle-back oil *Gasterosterus tracherus*	...	...	...	...	...	...	...	...	95·78
71 Sunflower oil *Helianthus annuus*	0·924— 0·926 (15°)	...	1·4611 (60°)	1·4531	−16 to −18·5	S.P. 17 —18	...	17—24	95
72 Tallow (Mutton)	0·937—0·953	...	1·4501 (60°)	1·4374	36—41	43·2—46·1	44—49	46—54	95·54
73 Tallow (Beef), see Beef Tallow									
73 Tung oil, see Chinese or Japanese Tung oil.									
74 Walnut oil *Juglans regia*	0·9259	...	1·4804	...	−27·5	S.P. 16	...	15—20	95·4
75 Whale oil *Balæna species*	0·9170 (15°) —0·9272	0·8822 (100/100)	1·4762 (20°)	1·4348	below −2	22·9—23·9	...	27	93·5
76 White mustard oil, see Mustard oil.									
77 Wool fat, Wool wax or Wool grease	0·941— 0·945 (17°)	...	1·4781— 1·4822(40°)	...	30—30·2	S.P. 40	31—42·5	41·8	...

	Unsaponifiable matter.	Saponification value mgrms. KOH for oil, &c.	Neutralisation value of fatty acids.	Iodine value % Oils, &c.	Iodine value % Fatty acids.	Maumené's Test, 0°C.	Reichert-Meissl value cc. N/10 KOH.	Mean mol-wt. of fatty acids.	Acid value.	Other data.
68	37—41·5	123·4—147·4	...	70·4—96·4	83·2	51	0·60	281—300	2—4	Butyrorefractometer at 40°C. 44·5 "degrees."
69	...	199·9—203·5	201·3	19·3—25·7	23·6	...	...	...	...	
70	1·73	183·2—192·6	...	162	...	...	...	287·4	21·6	
71	0·31	188—194	201·6	119·7—135	124—134	72—75	...	...	11·2	
72	...	192—195·2	198	34·8—46·2	34·8	...	...	275—285	1—50	
73										
74	...	188·7—197·3	...	182·1—151·7	150·05	96—110	...	...	...	
75	0·2—4·0	187·9—194·2	...	110—146	130·3—132	85—92	Reichert value 0·7—2·04	...	0·5—60	Ether-insoluble bromides, 27·8%
76										
77	...	102·4	...	17·1—28·9	17	...	...	327·5	...	

ESSENTIAL OILS.

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When examining essential oils, it should be remembered that, as they are natural vegetable products, their composition and character are greatly affected by climatic and other conditions under which they have been formed. It is therefore inadvisable to stipulate inelastic specifications; careful judgment must be exercised, as the sophisticator is not slow to take advantage of this situation. Among other precautions, tests should invariably be made of the odour; such tests will not infrequently indicate in which direction adulteration should be sought. In cases of doubt it is often useful to compare the oil under examination with one of undoubted purity.

The tests usually applied are physical and chemical. The physical tests comprise: specific gravity; optical rotation; refractive index; solubility in alcohol; melting or solidifying point; distillation tests. The chemical tests include estimations of certain general and specific constituents of the oils, such as: acids, esters, alcohols, phenols, aldehydes and ketones.

Physical Tests.

(1) *Specific gravity.* Specific gravity bottles of 50 cc. capacity are the most suitable instruments for this determination; pyknometers are specially useful if the quantity of oil available is small. The coefficient of expansion of essential oils is high, being of the order of 0·001; it is therefore necessary to adjust carefully the temperature at which the determination is made. The temperature most generally employed is 15°C.; sometimes 60°F., *i.e.*, 15·5°C., is used. The United States Pharmacopœia has adopted a standard temperature of 25°C., and this is generally used in warm climates. Higher temperatures are also necessary for oils which are solid at 15°C., such as otto of rose (30°C.) and aniseed oil (20°C.). The specific gravity bottle or pyknometer must be calibrated at the temperature used in making the test.

(2) *Optical rotation.* This is expressed in terms of the angular rotation of sodium light passing through a 100 mm. length of the oil at 20°C. Accurate temperature adjustment, although desirable, is not essential, the error produced by a temperature variation of 1°C. or 2°C. being relatively small.

It is always advisable thoroughly, but quickly, to filter the oils as a slight cloudiness makes accurate adjustment difficult; oils having a green colour, such as bergamot, are particularly opaque to sodium light, and it is generally necessary to

employ short containing tubes. With some oils of very low optical activity, such as fennel oil, the greatest care must be taken, and the zero of the instrument must be carefully checked.

(3) *Refractive index.* The most suitable instrument is the jacketed Hilger-Abbé refractometer, which has the great advantages that a determination accurate to 1 or 2 in the fourth decimal place may be made with only two or three drops of the oil, and that ordinary daylight may be used. Other instruments occasionally employed are the Pulfrich and the Féry.

The temperature of the oil is adjusted carefully to the standard temperature of 20°C.; the U.S.P. quotes 25°C., and there is a general tendency for the use of this higher temperature. The refractive index diminishes with rise of temperature; an approximate correction which may be applied is ± 0.00045 per 1°C.

(4) *Solubility in alcohol.* This test is conducted by shaking 1 cc. of the oil in a stoppered graduated 10 cc. measuring cylinder with alcohol of definite strength, added 1 cc. at a time, until complete solution is obtained. The usual strengths of alcohol employed are 90%, 80% and 70% by volume, but both higher and lower strengths are occasionally used. The test should be conducted at a temperature of 20°C., but this precaution is not invariably observed.

This test is of great value in testing terpeneless and sesquiterpeneless oils. The former are generally soluble in less than 5 volumes of 80% alcohol, and the latter in less than 5 volumes of 70% alcohol. Certain essential oils, especially stale or resinified oils, never yield a completely clear solution, while other oils first dissolve, and on the addition of more alcohol become cloudy. The solubility test was formerly practically the sole criterion by which Ceylon citronella oil was judged (Schimmel's test), but of recent years more scientific tests have been used.

Proposals have been made to establish a test known as the "solubility value." This value is determined by dissolving 5 cc. of the oil in 10 cc. of absolute alcohol (67 O.P.), and then adding water from a burette until a permanent turbidity is just produced. The number of cc. of water added multiplied by 100 is termed the "solubility value."

For specific gravities of alcohol-water mixtures, see "Physico-Chemical Constants" section.

(5) *Melting- and solidifying-points.* This test is only applicable to those oils which are solid at normal temperatures, such as aniseed, fennel, and rose oils. It can be

carried out in an ordinary test-tube, except when highly accurate results are required, in which case it is best to employ a Beckmann freezing-point apparatus. The thermometer employed for the determination should be accurate and graduated to one-tenth degrees over a range of $-10°$ to $+50°C$.

Difference of opinion exists regarding the relative accuracies of the melting-point and the solidifying-point determinations. In the opinion of the writer, the solidifying-point, if the operation be properly carried out, is more definite than the melting-point, but in any case, the " personal equation " of the operator tends to vary the results.

It is advisable to make an approximate estimation of the solidifying- and melting-points before making an accurate determination. Accurate results may be obtained as follows :

A convenient quantity of the oil, say 5 cc. of aniseed oil, is placed in a clean, dry, stout-walled test-tube, the oil completely melted, the tube immersed in iced water (a freezing mixture of ice and salt may be used if necessary, but excessive supercooling must be avoided), and the oil gently stirred with the thermometer. When the temperature has dropped about 5° below the solidifying-point of the oil, previously determined, the test-tube is removed, the outside quickly dried, and crystallisation induced by the addition of a small crystal of a separately solidified portion of the oil. The oil is stirred vigorously, and the maximum temperature attained is noted ; this temperature is the solidifying-point. The stirring is continued until the oil melts, using if necessary an air-bath 4 or 5 degrees above the solidifying temperature of the oil, and the temperature noted at which liquefaction takes place, usually a degree or two above the solidifying-point. Essential oils, being mixtures, do not have very definite melting-points, and it is difficult to decide which is the exact temperature of liquefaction ; it is sometimes considered preferable to determine the temperature at which the liquid becomes clear or completely molten.

(6) *Distillation tests.* These as a rule are not resorted to unless adulteration is suspected. Sometimes, however, failing a better method, a particular constituent of an oil is roughly estimated by fractional distillation, *e.g.*, anethole in aniseed oil. If adulteration is suspected, the best procedure is to distil the oil into 10% fractions, and to examine the functions, comparing them with fractions obtained under identical conditions from a similar oil of undoubted purity. It is generally necessary to distil under diminished pressure (10 to 20 mm.) in order to avoid decomposition. The determination of the refractive indices of the various fractions

is usually sufficient to indicate adulteration. The boiling ranges and odours also serve as very useful guides. The procedure which should follow will depend on the results obtained and must be left to the judgment of the operator. Often it is possible to isolate by fractional distillation the substance used for the adulteration. The test is sometimes conducted by taking fractions over definite boiling-point ranges instead of in 10% fractions.

(7) *Odour test.* The quality of an oil can often be gauged fairly accurately by smelling a drop rubbed on the back of the hand, but it is better to make a comparison with an oil of known authenticity and quality, by placing a drop of each oil respectively on two pieces of filter-paper, and smelling them alternately; it must be remembered that a process of fractional evaporation is proceeding continually. Advantage may be taken of this fractional evaporation by comparing slips of filter-paper impregnated with the oil at different times, after partially allowing to evaporate. The odour test may also be conducted by comparing the odours in two similar beakers, each covered with a clock-glass, and at the bottom of which have been placed just one drop of the two oils respectively. The tests should be conducted in an odour-free atmosphere, and under clean conditions.

Chemical Tests.

(1) *Acid value and Ester value.* The acid value estimation is not usually of much critical value, but is a necessary preliminary to a subsequent ester determination, and may be conducted with the sample used for the latter. Most oils are practically neutral, but tend to acquire acidity by oxidation.

For the dual determination the procedure is as follows :—
Into an alkali-free glass flask of about 200 cc. capacity is weighed out accurately 2 to 5 grm. of the oil (according to the probable magnitude of the ester content), about 2 cc. of neutral distilled water is added, and the free acidity titrated with $N/10$ sodium or potassium hydroxide, using phenolphthalein as indicator. The acid value is expressed as the number of milligrams of potassium hydroxide required to neutralise one gram of the oil.

25 cc. of N or $N/2$ alcoholic sodium or potassium hydroxide solution (recently checked) is added, and the solution refluxed on a water-bath for one to two hours; the solution is cooled and the excess of alkali titrated with N or $N/2$ sulphuric or hydrochloric acid.

If the identity of the ester in the oil be unknown, the results may be returned in terms of milligrams of potassium

hydroxide consumed by one gram of the oil (ester number), but it is usual to refer the result to the predominating ester, *e.g.*, linalyl acetate in lavender or bergamot oils: geranyl tiglate in geranium oil; menthyl acetate in peppermint; methyl salicylate in wintergreen oil. The ester percentage is calculated from the following formula :—

$$\frac{\text{No. of cc. of N. alkali} \times \text{Mol. wt. of ester}}{10 \times \text{Wt. of oil}}$$

The following are the molecular weights of a few of the more usually occurring esters :—

Benzyl acetate	150	Menthyl and citronellyl ace-		
Methyl anthranilate	151	tates		198
Methyl salicylate	152	Geranyl tiglate		236
Sabinyl acetate	194	Santalyl acetate		262
Geranyl, linalyl, terpinyl, and bornyl acetates ..	196			

It should be remembered that other bodies, such as aldehydes and lactones, may be included in the ester value as determined by hydrolysis with caustic alkali. For the detection of the addition of substances which elevate the ester value fictitiously, see " Detection of adulterants."

(2) *Estimation of alcohols.* Alcohols, such as geraniol, menthol, linalool, etc., are estimated by first converting them into their acetic esters, and then re-determining the ester value of the acetylated oil.

The process has been standardised to some extent, but variations are necessary as indicated in the case of certain oils :—

10 cc. of the oil is boiled gently under a reflux air-condenser for 2 hrs. with 20 cc. of acetic anhydride (95—100%) and 2 grm. of recently-fused, anhydrous sodium acetate. The liquid is cooled, about 100 cc. of water added, and warmed on the water-bath to about 80°C for 15 mins. with occasional shaking, in order to decompose the excess of acetic anhydride. The mixture is transferred to a separating-funnel, and the oil washed once with cold water (or brine, if the separation is poor due to the formation of an emulsion), then with 1% sodium carbonate solution until the mixture remains distinctly alkaline, and finally with distilled water until neutral. The oil is separated, and dried over neutral anhydrous sodium sulphate, filtered, and the new ester value estimated as previously detailed.

The percentage of alcohols may be calculated from the formula :—

$$\frac{\text{No. of cc. of N. alkali} \times \text{Mol. wt. of alcohol}}{10 \ (\text{Wt. of acetylated oil} - 0 \cdot 042 \times \text{No. of cc. N. alkali})}$$

If the original oil contained esters other than acetates, this formula does not give strictly accurate results; for more accurate results it is necessary to hydrolyse the oil before acetylating, and then to calculate the results to the original oil. The amount of free alcohol may be calculated as follows :

$$\% \text{ free alcohol} = \frac{(B - A) \, Y}{0 \cdot 42106 \, (1335 \cdot 5 - B)}$$

where

  A is the saponification value of the original oil;
  B „ „ „ „ „ after acetylating;
  Y „ „ molecular weight of the alcohol, if monohydric

The following are the molecular weights of the most usually occurring alcohols :—

Benzyl alcohol	108
Phenyl ethyl alcohol	122
Geraniol, linalool, terpineol, borneol	154
Rhodinol, citronellol, menthol ...	156
Santalol	220

The alcohols linalool and terpineol are dehydrated by the action of acetic anhydride, terpenes being formed, but fairly accurate results may be obtained if the oil be first diluted with an equal weight of turpentine or xylene, a blank having been performed on the diluent and allowed for.

Certain oils, such as citronella, contain the aldehyde citronellal, which, under the action of acetic anhydride, isomerises to the ring alcohol isopulegol, the alcohol value being raised correspondingly. In such cases it is usual to return the result as obtained by the standard method as " total acetylisable constituents," calculated as geraniol. Java citronella oil, usually having a total acetylisable constituent value of over 90%, needs more acetic anhydride than used in the standard method, to acetylate it completely; 30 cc. of 95—100% acetic anhydride should be used in place of the usual 20 cc.

It is becoming more usual to differentiate between the geraniol and the citronellal of Java citronella oils, and this is done by converting the aldehyde into its oxime, thus preventing its isomerisation into isopulegol, and then re-estimating the alcohols. The procedure is as follows :—

10 grm. of hydroxylamine hydrochloride is dissolved in 25 cc. of water, and a solution of 10 grm. of potassium carbonate in 25 cc. of water added; the mixture is filtered and shaken thoroughly with about 10 grm. of the oil for 2 hrs. at 15°—18°C. The oil is separated, dried over neutral

anhydrous sodium sulphate, filtered, and treated as described for alcohol estimations.

The difference between the value thus found for the geraniol itself and the value for the total acetylisable constituents calculated as geraniol, represents the citronellal content.

The alcohol citronellol may be approximately estimated in the presence of geraniol, *e.g.*, in otto of rose, by treatment with 100% formic acid. The geraniol is dehydrated to a terpene, but the citronellol is formylated. The processs is as follows :—

A mixture of 10 cc. of the oil with 10 cc. of 100% formic acid (Sp. Gr. 1·22) is gently refluxed for 1 hr., then cooled, shaken with 100 cc. of water, the oil separated, and submitted to the process for the determination of esters. The percentage of citronellol is given by the formula :—

$$\frac{\text{No. of cc. of N. alkali} \times 15 \cdot 6}{\text{Wt. of formylated oil} - (\text{No. of cc. of N. alkali} \times 0 \cdot 028)}$$

(3) *Aldehydes and ketones.* Two methods are in general use ; one is applied to oils containing a large proportion of aldehyde or ketone, and the other, when these are present only in small proportions, *e.g.*, up to 10%.

Sulphite method. This is suitable for the estimation of aldehyde in oil of lemongrass, cassia, cinnamon bark, almond, terpeneless and sesquiterpeneless lemon, and methyl ketones such as methyl heptenone.

5 or 10 cc. of the oil is accurately pipetted into a flask of 150 cc., or, better, 250 cc. capacity, the neck of which is long and narrow and 10 cc. of which is graduated in 0·1 cc. (Cassia flask). To this is added about an equal volume of hot sodium bisulphite solution (30—35% strength), and the mixture well shaken for a few mins. ; frequently, however, the mixtures becomes solid almost immediately, and further quantities of bisulphite solution are added from time to time with frequent shaking, and the whole is kept hot on a boiling-water bath until the solid first formed is completely dissolved, and only oil remains ; the flask is then filled with bisulphite solution, so as to bring the unabsorbed oil up into the graduated portion of the neck ; it is then set aside to cool, and for the unabsorbed oil to float out. The difference between the original volume of the oil and that unabsorbed is a measure by volume of the aldehyde content of the oil.

Cassia oil is not infrequently "adjusted" by the addition of colophony ; in such cases, it is advisable to prolong the heating for several hours, as this aids the ultimate floating out of the unabsorbed portion. In cases where an emulsion

forms between the oil and the aqueous solution so as to obscure the partition, it can sometimes be broken up by the addition of a known volume of benzene or petroleum ether, the addition being allowed for in the final reading.

The process is sometimes carried out by using neutral sodium sulphite solution, instead of bisulphite; in this case, sodium hydroxide is formed during the reaction, and must be neutralised by the gradual addition of dilute acid until no further alkalinity is shown by phenolphthalein. This method is preferable to the other in that it shows when the absorption is complete. It generally gives slightly lower results than the bisulphite method, as under these conditions, bodies such as methyl heptenone are only very slowly absorbed; hence for lemon-grass oil the neutral sulphite method is to be preferred. The amount of acid added to neutralise the alkalinity developed is also a measure of the aldehydic content of the oil but, owing to the indefinite " end point," the method is not employed.

Hydroxylamine method. This method is the best for the estimation of citral in oils of lemon, citron, limes (H.P.), etc. It is also reliable for other aldehydes, and is used when the sulphite method is not suitable on account of a low aldehydic content. This method requires considerable practice, even in the hands of experienced chemists. It is conducted as follows :

20 grm. of oil of lemon (for example) is weighed accurately into a 250 cc. conical flask, and to it are added in the order named, 20 cc. of alcohol (60 O.P.), 20 cc. of N/2 hydroxylamine hydrochloride in 80% alcohol, and 8 cc. of N. alcoholic potassium hydroxide. The mixture is gently boiled on a water-bath for exactly one hour, under a really efficient reflux condenser. The flask is then cooled, and the contents diluted to about 250 cc. by washing through the condenser with freshly-boiled distilled water. The undecomposed hydroxylamine hydrochloride is then exactly neutralised with N/2 potassium hydroxide, using phenolphthalein as indicator, and the hydroxlamine thus liberated titrated with N/2 sulphuric acid, methyl orange being used as an external indicator on a spotting tile. The end point is not very distinct, and the titration must be done rapidly. A blank test is conducted under exactly the same conditions, the oil being omitted. The difference between the titrations with methyl orange represents, in terms of N/2 cc., the hydroxylamine combined with the aldehyde. In the case of lemon oil, this figure must be multiplied by 0·38 to give the percentage by weight of citral in the oil (*cf.* British Pharmacopœia). For other mono-aldehydes, the percentage is given by—

(No. of cc. of N/2 hydroxylamine×Mol. wt. of aldehyde)/400.

The hydroxylamine hydrochloride solution used for this process should not be made up in bulk, as it tends to give erratic results after the lapse of a day or two. The method gives results 5 to 10% low, and is not suitable for use with oils containing large proportions of aldehyde, nor for the estimation of citronellal.

(4) *Phenols.* These are estimated by absorption in a " Cassia flask " (see aldehyde estimation—sulphite method) by 5% potassium hydroxide. 5 or 10 cc. of the oil, accurately pipetted, are shaken in the flask with 100 to 150 cc. of the alkali solution, the mixture being heated on a boiling water-bath. The absorption is complete for about 1 hr., and the flask is then filled up with the alkali solution, set aside for about 12 hrs. to allow the oil to separate out, and measured. The process is suitable for estimating eugenol, thymol, etc.; the results tend to be too high on account of the absorption of small quantities of non-phenols, and for this reason the use of stronger alkali solution is to be avoided.

(5) *Estimation of eucalyptole (cineole).*

Phosphoric acid method. This is the official method of the British Pharmacopœia, but is not very accurate. Concordant results can only be obtained by experienced operators. It is the method usually adopted in commerce, but a more accurate method, the cresinol method, is replacing it.

The phosphoric acid method is conducted as follows :— 10 to 20 grm. of oil is weighed accurately into a small beaker, and to it are added, drop by drop, with stirring and cooling one to one-and-a-half times its weight of pure phosphoric acid of Sp. Gr. 1·750. The crystals which rapidly form are quickly but thoroughly pressed between dry filter-paper, all adherent liquid being removed as far as possible; they are then placed in an accurately graduated measuring cylinder, and mixed with warm water. The eucalyptole-phosphoric acid compound is thereby decomposed, and the eucalyptole separates out and can be measured after cooling; the weight is calculated by multiplying the volume by 0·93. In order to check the accuracy of the estimation the oil layer should be separated, dried over anhydrous sodium sulphate, filtered, and its melting-point ascertained; this should not be lower than −3°C. (pure eucalyptole melts at +1·2°C.). It is well to remember that eucalyptole is a body of relatively high volatility, B.Pt. 177°C. In order to aid the removal of the terpenes, the crystals may be washed on a Buchner funnel with dry petroleum ether of low boiling point, but all moisture, even atmospheric, must be carefully excluded, as water readily decomposes the compound, and low results may be obtained.

The phosphoric acid method is not suitable for oils containing less than 40% of eucalyptole; such oils may have the eucalyptole content raised by the addition of a known proportion of pure eucalyptole, or by careful fractional distillation before performing the estimation.

Cresineol method. This method consists in determining the freezing-point of a mixture of *o*-cresol with the eucalyptus oil; it gives slightly higher results than the phosphoric acid method, but the probability of error is within the limits of ±3%. It is carried out as follows :—

Into a stout-walled test-tube, about 15 mm. by 80 mm. in size, are weighed out accurately exactly 3 grm. of the oil, and 2·1 grm. of melted *o*-cresol. The tube is then inserted, through a suitably bored cork, into a wide-mouthed bottle. The mixture is stirred with a thermometer, graduated 0—100°C. in 1/10th degrees, and the solidifying-point noted. The solidifying-point is the temperature at which solid cresineol separates; the mixture is permanently liquid at the temperature of the test. The mixture is then completely melted, and the solidifying-point again noted, the operations being repeated until concordant results are obtained. With oils which are low in eucalyptole content it is sometimes necessary to "seed" the superfused liquid with a crystal of the eucalyptole-cresol compound "cresineol." Pure cresineol solidifies at 55·2°C. and pure *o*-cresol at 30°C. The percentage of eucalyptole is estimated from the following table, or, better, from a curve constructed from the table :—

% Eucalyptole.	F. Pt.	% Eucalyptole.	F. Pt.
100	55.2°C.	70	42.2°C.
95	53.5	65	39.3
90	51.5	60	35.8
85	49.1	55	31.3
80	46.8	50	27.6
75	44.5	45	24.2

The freezing point is the temperature at which the solid cresineol separates from the mother liquor. The mixture is permanently fluid at the temperature of the test.

The method may also be applied to oils of low eucalyptole content, such as spike, lavender, and rosemary, by the addition of a known proportion of pure eucalyptole before performing the determination.

(6) *Stearoptene or fixed-residue.*

This estimation is usually only carried out with oils obtained by expression : it is also of value if adulteration with substances of high boiling-point is suspected. It is carried out by evaporating a known weight (10 grm.) of the oil on a boiling water-bath, until the loss in weight in 10 to 15 mins. is negligible. The character of the residue

should be noted, and, if thought necessary, further tests applied. The following are some typical results for pure oils : lemon, 2—6% ; sweet orange, 1·5—4% ; bitter orange, 2·5—4·5% ; tangerine, 2—4% ; bergamot, 4·5—6·5% ; H.P. limes, 9—18% ; rose (Bulgarian), 15—20%.

Detection of adulterants.

Adulteration is often detected by abnormality of the physical or chemical data usually determined. It is impossible to do more than indicate a few special tests by means of which the more common adulterants may be detected.

Petroleum distillates. Indicated by : odour, insolubility, and distillation tests ; low refractive index and Sp. Gr. ; stability to fuming nitric acid, concentrated sulphuric acid, potassium hydroxide, etc.

Turpentine oil. Indicated by : odour, insolubility, optical rotation (especially of first 10% fraction) ; low B.Pt. ; and formation of hydrochloride, M.Pt. 125°C., and nitroso chloride, M.Pt. 103°C.

Fixed animal and vegetable oils. Indicated by : high residue on evaporation ; insolubility (except castor oil) ; increase of ester value ; decomposition on heating (acrolein odour).

Fatty acids. Indicated by high acid value.

Cedarwood, copaiba, and Gurjan balsam oils. Indicated by : high B.Pt., Sp. Gr., and refractive index ; abnormal optical rotation ; solubility. Gurjan balsam oil gives an intense violet coloration when a few drops of conc. nitric acid are added to an acetic acid solution.

Alcohol, acetone, and chloroform. Indicated by : low B.Pt. and refractive index ; odour. Alcohol may be detected and approximately estimated in otto of rose by noting the increase of refractive index after washing with water.

Resins (especially in Cassia oil). Indicated by : dark colour ; precipitate with lead acetate solution ; high non-volatile residue ; high acid value.

Terpenes. Indicated by : general lowering of the quality of the oil ; low Sp. Gr. and refractive index ; solubility ; and generally by high optical rotation.

Artificial esters, etc. (especially in bergamot and lavender). These are often difficult to detect ; the general characteristics of the oil frequently give no indication of the addition. The following adulterants have been found : glyceryl acetates, terpinyl acetates, ethyl and methyl esters of acetic, citric, tartaric, oxalic, succinic, benzoic, lauric, oleic, and phthalic acids ; fatty oils and acids.

The best method for the detection of added esters is

generally to isolate the acids and identify them; the commonly naturally occurring acids are acetic, butyric, valeric, and tiglic, and occasionally benzoic and salicylic. Glyceryl and terpinyl acetates, etc., may be detected as follows :—

Glyceryl acetate. 10 cc. of the oil are shaken with 20 cc. of 5% alcohol, separated, and the aqueous layer filtered to clearness, exactly neutralised with $N/10$ alkali, and the ester value estimated; 0·6 cc. of $N/2$ alkali represents 1% of glyceryl acetate; an allowance of about 0·2 cc. must be made for the amount of pure oil dissolved. As confirmatory tests, the refractive index and ester value of the washed and dried oil may be compared with those of the original sample. Glyceryl acetate elevates both these figures. The refractive index of glyceryl triacetate is μ_D^{15} 1·4328; 1% elevates the apparent linalyl acetate content of bergamot or lavender oil by 2·62%.

Terpinyl acetate. This may sometimes be detected by its odour. It is estimated by a process of fractional hydrolysis, advantage being taken of the fact that terpinyl acetate is more slowly hydrolysed than is linalyl acetate. The ester values obtained after boiling for 30 mins. and 2 hrs. with $N/2$ alcoholic caustic alkali should not differ by more than one unit with pure oils, but the presence of each 2% of terpinyl acetate causes approximately a difference of one unit.

Artificial esters of non-volatile acids, such as oxalates, citrates, tartrates, phthalates, etc., may be detected by steam distilling to exhaustion, with a sufficiency of sulphuric or phosphorus acid, the solution remaining from the determination of the ester value (sulphuric and not hydrochloric acid must be used for the back-titration). The amount of volatile acid in the distillate is then determined, and should correspond with that indicated by the saponification value. A blank should be run under identical conditions, with the omission of the oil. Example : An oil containing 2% of ethyl citrate yielded a direct saponification value of 109·1, the "volatile acid value" was 92·8; an oil containing 5% of ethyl succinate gave 127·6 and 91·5 respectively.

The following are the more important publications on the subject :—

E. J. Parry. "The Chemistry of the Essential Oils and Artificial Perfumes." 2 vols.
Gildermeister and Hoffman. "The Ethereal Oils." 3 vols.
Allen's "Commercial Organic Analysis," Vol. IV.
Sydney Young. "Distillation Principles and Processes."
Heusler-Pond. "The Chemistry of the Terpenes."
Perfumery and Essential Oil Record.

Properties of the Essential Oils.

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index at 20°C.	One part soluble in parts alcohol.	Other data and information
Ajowan oil *Carum ajowan,* *Ptychotis ajowan*	3—4	Thymol (38—60%), thymene, a mixture of cymene and terpinene.	0·910 —0·930	+1° to +5°	1·4980 —1·5005 (35°C.)	3 (70%)	Found in India, Persia, Afghanistan
Almond oil, bitter *Prunus amygdalus amara* (kernels) Peach and apricot kernels with HCN	0·5—1	Benzaldehyde (99%), prussic acid, benzaldehyde cyanhydrin. Natural oil 2—5% HCN.	1·045 —1·060	Inactive	1·542 —1·546	2 (70%)	Found in Europe, Asia, N. Africa, California
Anise oil (Aniseed) *Pimpinella anisum* (fruits)	2—3	Anethol (80—90%), methyl chavicole, anisic aldehyde, anisic acid in old oil.	0·975 —0·990 (20°)	0° to -2°	1·552 —1·558 (25°C.)	3—5 (90%)	M.pt. 17—20°C. Found in Russia, Germany, France, Spain, Netherlands
Anise oil (star) *Illicium verum*	3	Anethol (80—90%), *p*-cymene, *d*-pinene, *l*-phellandrene, methyl-chavicole, anisic aldehyde, anisic acid, cineole, safrole, terpineol, and a sesquiterpene.	0·975 —0·990 (20°)	-2° to +1°	1·551 —1·558 (25°C.)	3 (90%)	M.pt. after solidification 17°—19°C. Found in China and Tonkin
Bay leaves oil *Pimenta acris* (*Myrcia acris*)	2—3	Eugenol, methyl-eugenol, and *l*-phellandrene; traces of chaviol, methyl chavicole, citral, & myrcene.	0·950 —0·990	0° to -3°	1·510 —1·520	Freshly distilled, miscible (90%)	Contains phenols (eugenol 50—75%). Found in West Indies
Bergamot oil *Citrus bergamia* (peel of fruit)	0·5—1	Linalyl acetate (35—45%), linalol, limonene, pinene, octylene, camphene, dipentene, and a stearoptene of M.P. 188°C.	0·881 —0·887	+8° to +20°	1·460 —1·489	0·3	Found in Calabria. Non-volatile residue at 100°C. 5—6%
Cade oil *Juniperus oxycedrus*	1·6—3·4	The sesquiterpene, cadinene, B.P. 274·275°.	0·995 —1·025	ca. -30°			By destructive distillation of the wood

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15°C.	Optical rotation at 20° C.	[Refr. index] at 20°C.	One part soluble in parts alcohol.	Other data and information.
Cajuput oil *Melaleuca minor, M. Leucodendron, etc* (leaves and twigs)		Cineol (Eucalyptol) (45—65%) terpineol, *l*-pinene; traces of valeric aldehyde and benzaldehyde.	0·917 —0·930	0° to - 4°	1·460 —1·470 (25°C.)	3 (80%)	Found in India and Australia. Often contains copper.
Camphor oil (light) *Cinnamomum camphora (Camphora officinalis, Laurus camphora)* (wood)		Light fractions : Pinene, phellandrene, limonene, dipentene, camphor, oineol, terpineol.	0·860 —0·950	+ 12° to + 32°	1·465 —1·481	3 (90%)	Found in China, Japan and Formosa.
Camphor oil (heavy)		Heavy fractions : Safrol, camphor, eugenol, cadinene.	0·950 —1·000	0° to 12°	1·500 —1·508	3 (90%)	U.S.A. experimenting on growth of camphor trees.
Cananga oil *Canaga odorata* (flowers)	1·5—2	Contains a greater proportion of sesquiterpenes than ylang ylang oil; esters of benzoic and acetic acids, linalol, geraniol, nerol, farnesol, iso-eugenol, pinene, cresol, para-cresyl methyl ether, cadinene.	0·906 —0·967	-15° to - 87°	1·474 —1·508	1—2 (90%)	First part of re-distilled oil sold as ylang ylang oil q. v. Sap. val. 40—160, Java variety sap. val. 10—60. Found in Philippines and Malay Archipelago, Islands of Luzon and Java
Caraway oil *Carum carui* (seeds)	3—7	Carvone (50—60%), *d*-limonene d-acetaldehyde, and methyl puperal; H_2S produced during distillation.	0·907 —0·920 (B.P. minimum 0·910)	+ 70° to + 89° (usually + 75° to + 78°)	1·484 —1·497 (25°C.)	10 (80%)	Found in Europe (Holland) and Asia
Cardamom oil *Elettaria cardamomum* (seeds)	3·5—8	Cineol, terpineol, limonene, terpinene, sabinene.	0·922 —0·950	+ 22° to + 40°	1·460 —1·470	2—5 (70%)	Found in Southern India and Ceylon Ester val. 90—150.

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index] at 20°U.	One part soluble in parts alcohol.	Other data and information.
Oassia oil *Cinnamomum cassia* (leaves, twigs, bark)	0·5—2	Cinnamic aldehyde (75—90%), terpenes, cinnamic esters, phenyl propyl acetate.	1·055—1·072	+6° to −1°	1·585—1·606	3—4 (70%), 2 (80%)	Found in Oochin China, cultivated in China. Often adulterated with resin (10%)
Cedar leaf oil *Juniperus virginiana* (leaves)		Limonene, cadinene, borneol, borynl esters.	0·883—0·900	+55° to +65°	1·495—1·510	Insol. (80%)	Commercial cedar leaf oil often derived from *Thuja occidentalis*
Cedar wood oil (Virginian red cedar) *Juniperus virginiana* (wood)	2·5—5·0	Cedrol (8—10%), the sesquiterpene cedrene and the alcohol cedrenol.	0·940—0·962	−25° to −47°		10—20 (90%)	From waste wood
Oedrat or Citron oil *Citrus medica* (peel) Celery oil *Apium graveolens* (fruit)	2·5—3	Limonene, citral (5—6%), dipentene. Terpenes (90%), palmitic acid, guaiacol, the lactone sedanolid, sedanolic acid, sedanonic anhydride (last two are the cause of the odour).	0·851—0·854 0·860—0·895	+77° to +89° +60° to +80°	1·4750 1·479—1·486	10 (90%)	Fruit used for candied peel Cultivated in European countries; contains no pinene
Chamomile oil (Roman chamomile) *Anthemis nobilis* (flowers)	1	Angelic and tiglic esters of isobutyl, amyl, and hexyl alcohols, anthemol. Blue constituent is a sesquiterpene; B.P. 295—300°	0·905—0·920	−3° to +3°	1·442—1·465 (25°C.)	6 (70%)	Sp. Gr. 0·9738 at 25°. Soln. in phosphoric acid is fluorescent. Found in Germany, Great Britain, France, Belgium

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]D at 20° C.	One part soluble in 90% alcohol	Other data and information.
Chamomile oil (German chamomile) *Matricaria chamomilla* (flowers)	0·2—0·5	Chamomillol $C_{10}H_{16}O$, trichamomillol $C_{15}H_{24}O$, esters of caproic acid, solid hydrocarbon, furfural, umbelliferone, methyl ether.	0·920 —0·955	0°	1·364	Freely in 90%	Solid at 1°C.
Champaca flower oil *Michelia champaca*		Benzyl alcohol, geraniol, linalol and esters, iso-eugenol, methyl anthranilite.	0·907 —0·935	-12° to -52°			Found in Java and Philippines
'hampaca wood oil or *Bulnesia sarmienti*	4—8	Guaiol, M.P. 91°C.	0·965 —0·975	-3° to -8°	1·503 —1·505 (30°)	3—5 (70%)	Found in Argentine and Paraguay. Is semi-solid, melts to a liquid at 45°—55°C.
Cinnamon oil (Bark oil) *Cinnamomum zeylanicum*	0·5—1	Cinnamic aldehyde (55-75%), pinene, cymene, phellandrene, benzaldehyde, cumic aldehyde, nonaldehyde, methyl amyl ketone, and a little eugenol (up to 8%).	0·943 —1·040	0° to -3°	1·528 —1·591 (25°C.)	3 (70%) 10 (70%) Seychelles.	Found in Ceylon. Should not give blue colour with ferric chloride in alcoholic solution
Cinnamon oil (Leaf oil)	0·5—2	Eugenol (75-90%), safrol, very little cinnamic aldehyde.	1·045 —1·065	-1° to +1°	1·530 —1·540 (25°C.)	3 (70%)	
Citronella oil *Cymbopogon nardus* (grass, etc.) (1) Java	0·5—0·7	Citronellal and geraniol predominate.	0·885 —0·910	0° to -3°	1·465 —1·473	3—10 (80%)	Total acetylisable constituents calculated as geraniol 80—100%.
(2) Ceylon	0·25—1	Geraniol predominates with citronellal, camphene, etc.	0·898 —0·990	0° to -21° (average -12°)	1·478 —1·490	1—2 (80%)	Total acetylisable constituents calculated as geraniol 58—64%

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Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]b at 20°C.	One part soluble in parts alcohol.	Other data and information.
Clove oil *Eugenia caryophyllata* (buds)	14—21	Eugenol (80—95%), esters of eugenol, methyl alcohol, furfural and caryophyllene.	1·044 —1·069	0° to −2°	1·528 —1·540 (25°O.)	1—3 (70%)	Cultivated in the Moluccas, Zanzibar, Pemba, Sumatra, etc.
Clove oil (leaf)	4—6	Eugenol (75—93%). Chiefly sesquiterpenes (caryophyllene).	1·032 —1·067	0° to −2°	1·532 —1·539		Found in Seychelles
Copaiba oil (oleo-resin)			0·895 —0·918	−1° to −33°	1·493 —1·502 (25°C.)	20 (90%)	Para and Bahia balsams yield 50—65% oil, others yield 40—50% oil
Coriander oil *Coriandrum sativum* (fruit)	0·1—1	Coriandrol (*d*-linalol), and *d*-pinene.	0·870 —0·885	+7° to +14°	1·463 —1·476	3 (70%)	Found in most European countries. Total alcohols 45—55%
Cubebs oil *Piper cubeba* (fruit)	10—18	Cubeb camphor (M.P. 68—70°C., B.P. 245°C.), dipentene, *l*-pinene, camphene, cadinene.	0·910 —0·930	−25° to −42°	1·485 —1·502 (25°C)	1—10 (90%)	Found in Java and Singapore.
Cumin oil (Roman Caraway oil) *Cuminum cyminum* (fruit)	2·5—4·5	Cuminol (20—35%) cuminic aldehyde), cymene.	0·900 —0·930	+3° to +8°	1·494 —1·510	3 (80%)	Cultivated in Syria, Morocco, Malta & the East Indies. Sp. Gr. 0·893—0·899
Dill oil *Peucedanum graveolens, Anethum graveolens*	2·5—4	Carvone (30—60%), limonene, phellandrene.	0·895 —0·918	+70° to +82°	1·477 —1·490 (25°C)	3 (90%); 5—8 (80%)	Found in Caucasus and Mediterranean countries
Erigeron oil (Oil of fleabane, or bitter weed) *Erigeron canadensis* (herb)	0·26 —0·66	Limonene, terpineol citronellal.	0·850 —0·880	+45° to +81°		1 (95%)	Found in N. Amer. Oil resinifies on keeping

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]D at 20° C.	One part soluble in parts alcohol.	Other data and information.
Eucalyptus oil (leaves) *Eucalyptus amygdalina*	1·5—4	Contains 5—25% cineol, mainly phellandrene, piperitone.	0·855—0·890	-59° to -75°	1·476—1·480	3—10 (70%)	Eucalyptus species are indigenous to Australia, New Zealand and Tasmania. Cultivated in Spain, Algeria and California
Eucalyptus citriodora	1—1·5	Almost entirely citronella (85—90%) no cineol, traces of citronellol and geraniol.	0·865—0·905	-1° to +2°	1·454—1·467	4—5 (80%)	Indigenous to Queensland
Eucalyptus globulus (blue gum)	0·8—1·5	Cineol (55—70%).	0·910—0·930	0° to +12°	1·460—1·470	3—4 (70%)	Found in Tasmania
Fennel oil *Foeniculum vulgare* (F. capillaceum) (fruit)	4—6	Anethol (50—60%), fenchone (10—15%), M.P. +5 to +6°; dextro-pinene, and dipentene	0·960—0·990	+6° to +24°	1·525—1·550	5—8 (80%)	Cultivated in France, Italy, Roumania, Germany, India, Japan M.pt. after solidification +3 to +10°C.
Water fennel oil *Œnanthe phellandrium* (fruit)		Phellandrene (70—80%), pinene, sabinene.	0·850—0·894	+2° to +20°	1·484—1·495		Useless for flavouring

Name and source.	Yield per cent,	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]D at 20°C.	One part soluble in parts alcohol.	Other data and information.
Sweet fennel oil *F. dulce* (fruit)		High anethol content; no fenchone.	0·976 —0·980	+5° to +16° 30′			Found in South of France. M.pt. 10—15°C.
Wild bitter fennel oil (herb)		No anethol, some fenchone, phellandrene.	0·910 —0·925	+41° to +48°			Found in France, Spain, Algeria
Galangal oil (Chinese ginger) *Alpinia officinarum* (rhizome)	0·5—1·5	Cineol, pinene and cadinene.	0·915 —0·925	−1° to −6°	1·476		Indigenous to China and Siam
Geranium oils See Rose geranium oil							
Ginger oil *Zingiber officinale* (rhizome)	1—3	Phellandrene, camphene, zingiberene.	0·872 —0·886	−25° to −45°	1·488 —1·495	Insol. (95%)	Indigenous to tropical Asia
Ginger-grass oil *Cymbopogon Martini*, var. *sofia* (grass)	0·1	Geraniol (35—70%), geranyl acetate.	0·900 —0·955	−30° to +54°	1·478 —1·495	1—3 (70%)	Is an inferior kind of Palmarosa oil. More geranyl acetate than Palmarosa oil. Esters 5—25%
Guaiacum wood oil *Bulnesia sarmienti* (Champaca wood oil)	4—8	Is solid or semi-solid ; oil at 45°—55°C. Guaiol, M.P. 91°.	0·965 —0·975	−3° to −8°	1·503 —1·505 (30°)	3— 5 (70%)	Indigenous to the Argentine and Paraguay. Called Holy Wood. An adulterant of rose oil and sandalwood oil
Gurjum balsam oil Species of *Dipterocarpus*	45—70	Chiefly sesquiterpene.	0·915 —0·930	−35° to −130°	1·503 —1·505		

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]b at 20° C.	One part soluble in part⸗ alcohol.	Other data and information.
Hedeoma oil (American pennyroyal) Hedeoma pulegioides (fresh herb)	1·5	Pulegone (30%).	0·925 —0·960	+18° to +35°		1—3 (70%)	Indigenous to N. America
Hop oil Humulus lupulus (flowers)	0·3—1	Dipentene, linalol, geraniol, α-caryophyllene, humulene.	0·840 —0·872	0° to +1°	1·477 —1·490	Insol. 90%	
Jasmine oil Jasminum grandiflorum (flowers)	0·004 —0·006	Benzyl acetate (65%), linalyl acetate (7·5%), linalol alcohol (6%), benzyl indole, jasmone, methyl p-cresol methyl anthranilate.	0·920 —1·020	—1°15′ to +4°			Esters 41—73% as benzyl acetate.
Juniper berry oil Juniperus communis	1—2	Pinene, cadinene, juniper camphor, a sesquiterpene alcohol, M.P. 165°C., and its esters.	0·860 —0·890	—3° to —20°	1·472 —1·488 (25°C.)	4 (95%)	Found in Hungary, Italy. Juniper wood oil is a mixture of the berry oil with turpentine
Kuromoji oil Lindera sericea (leaves and twigs)		Linalol (40—50%), 10% esters (geranyl acetate).	0·890 —0·915	—2° to —22°		1—4 (70%)	Found in Japan
Laurel leaf oil Laurus nobilis	1—3	Cineol (25—50%), geraniol, methyl chaviicol, eugenol and esters of iso-butyric and valerianic acids.	0·915 —0·936	—15° to —22°		3 (80%)	Found in Asia Minor and Syria. Ester value 47
Lavender oil Lavendula vera (flowers)							

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]D at 20° C.	One part soluble in parts alcohol.	Other data and information.
1) English	0·8—1·7	Esters as linalyl acetate (7—10%), linalol, geraniol, nerol.	0·879 —0·900	-3° to -10°	1·460 —1·468 (25°Cl.)	3 (70%)	English oil is the most highly valued. Highest ester figure for a genuine oil 61·6
(2) French	0·5—1	Esters as linalyl acetate (25—45%).					Finest oils 35—40% esters
Lavendula spike oil *Lavendula spica* (flowers)	0·5—1·1	Linalol, borneol, camphor, cineol, terpineol, *d*-camphene.	0·906 —0·922	-2° to +12°	1·462 —1·468	3 (70%) 6 (65%)	Found in France. Spain and Italy. Total alcohols as borneol 25—45%. Esters as linalyl acetate 4—6%
Lemon oil *Citrus limonum* (peel)	0·8	Limonene (90%), citral (3·5—6%), higher aldehydes, octylic, nonylic, and decylic.	0·857 —0·862	+57° to +65°	1·473 —1·476 (25°Cl.)	10—12 (90%)	Found in S. Italy, Sicily. 1st 10% (vacuum) Oil. Rot. +52° to +60°
Lemon oil (conc.) (terpeneless)		Citral (40—50%).	0·895 —0·900	-5° to -9°	1·479 —1·483	1—2 (80%)	
Lemon oil (sesquiterpeneless)		Citral (60—75%).	0·900 —0·909	0° to -3°	1·483	3 (70%)	
Lemon-grass oil (Indian verbena oil) *Cymbopogon citratus* (grass)		Citral (α and β), citronellal, geraniol, limonene, and dipentene.	0·895 —0·905	-5° to +3°	—1·488	3 (70%)	Found in Ceylon and Straits Settlements. *C. flexuosus* for Malabar and Coohin oil
(1) East Indian	0·2—0·26	Citral (70—80%).	0·877 —0·887	-2° to +2°	1·484 —1·489	Insol. (90%)	
(2) West Indian	0·24—0·4	Citral (75—85%).		-5° to +3°			
Lignaloe *Bursera delpechiana* *B. aloexylon* (wood)	7—10	Linalol (55—75%), geraniol, terpineol, methyl heptenone.	0·875 —0·895	-5° to -13°	1·459 —1·465	3 (70%)	Found in Mexico

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr.] index at 20°C.	One part soluble in parts alcohol.	Other data and information.
Lime oil *Citrus limetta* (fruit) Hand pressed oil		Citral (6—10%), pinene, limonene, dipentene, linalol and ester, a stearoptene.	0·872 —0·902	+30° to +40°	1·476 —1·485		Found in Italy
Distilled oil *Citrus medica var. acida*		Practically no citral; pinene, limone, dipentene, oynene and sesquiterpene limene.	0·856 —0·868	+34° to +54°	1·470 —1·478		Found in West Indies and Montserrat
Mace oil (see Nutmeg oil)							
Marjoram oil *Origanum marjorana* (herb)	0·3—0·9	Terpinene, terpineol, terpin hydrate, borneol, camphor.	0·890 —0·910	+15° to +18°	1·472 —1·478	3 (80%)	Found in Spain
Matico oil *Piper augustifolium* (leaves)	0·5—6	Matico camphor (odourless, M.P. 94°), asarone (Sp.Gr. 1·077), terpenene, cineole, apiole.	0·938 —1·135	−30° to +6°	1·495 —1·530	10 (80%)	Found in tropical America
Mustard oil *Sinapis nigra* (seeds)	0·5—1·0	Allyl iso-thiocyanate (90—95%), allyl cyanide, carbon disulphide.	1·014 —1·032	Inactive	1·525 1·535 (25°C.)		
Neroli oil *Citrus bigaradia* *C. aurantium* (flowers)	0·08 —0·15	*l*-Linalol (30%), terpineol, limonene, linalyl acetate (7—20%), methyl anthranilate, indole, terpenes.	0·870 —0·885	0° to +45°	1·468 —1·477	3 (80%)	Neroli oil from bitter orange, Bigarade from sweet orange. Found in Portugal

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index] at 20° C.	One part soluble in parts alcohol.	Other data and information.
Nutmeg oil (seed)	7—15	Terpenes, alcohols, myristicin (4%).	0·865—0·930	+10° to +30°	1·475—1·489 (25°C.)	3 (90%)	Indigenous to the Moluccas, Banda and Sunda Islands. Not more than 5% residue when evaporated on a water-bath
Mace oil (ex arillus of nutmeg)			0·890—0·930	+10° to +20°	1·476—1·480	3 (90%)	
Orange oil Sweet orange oil *Citrus aurantium* (peel)		Limonene (90%), citral, decylic aldehyde, methyl anthranilate, terpineol, linalol.	0·846—0·852	+94° to +99°	1·472—1·478	3 (90%)	
Bitter orange oil *Citrus bigaradia* (peel)			0·848—0·856	+90° to +98°	1·472—1·475	3 (90%)	
Origanum oil *Var. species of Origanum* Trieste	2—3	Carvacrol, cymene.	0·940—0·980	+1° to -1°	1·475	3 (70%)	Phenols 60—85%
Smyrna	1·4—2·4		0·895—0·965	-1° to -15°		3 (70%)	Phenols 25—60%
Cyprus	0·1—0·2		0·960—0·970	0° to +1°		3 (70%)	Phenols 70—85%
Orris oil Iris species (rhizome)		Myristic acid (85%), irone (5—10%).	0·93—0·94	+12° to +30°	1·495	1·5 (80%)	A yellow mass M.pt. 44—50°C.; usually 38—45°C. Acid number 213—222
Palma-rosa oil (Indian geranium) *Cymbopogon Martini* (grass)	1	Geraniol, acetic and caproic ester, methyl heptenone, dipentene.	0·885—0·899	-3° to +5°	1·472—1·480	3 (70%)	Found in India. Esters 5—11%; total alcohols as geraniol 75—95%

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]D at 20°U.	One part soluble in parts alcohol.	Other data and information.
Parsley oil *Petroselinum sativum* (fruit)	2—7	Apiol (M.P. 30°C., 249°C.), terpenes.	B.P. 1·040—1·100	-5° to -10°	1·512—1·525	4—5 (80%)	Indigenous to Asia Minor and Mediterranean countries
Patchouli oil *Pogostemon patchouli* (leaves)	4	Cadinene (40—45%), patchouli alcohol (M.P. 56°C.).	0·950—0·995	-40° to -68°	1·504—1·520	10 (90%)	Found in Straits Settlements and West Indies. Sap. val. 4—18; after acetylation 35—80
Pennyroyal oil *Mentha pulegium* (herb)	0·1—0·2	Pulegone (75—80%).	0·930—0·960	+13° to +35°	1·475—1·486	2—3 (70%)	Found in Europe and N. America.
Peppermint oil Species of mentha herb		Menthol, menthyl esters, menthone, pinene, dimethyl sulphide.					
(1) English *Mentha piperita*	0·4—1·0		0·900—0·910	-22° to -33°	1·460—1·465	3—5 (70%)	Total menthol 55—70%; esters as menthyl acetate 3—15%
(2) American	0·1—1·0		0·900—0·920	-18° to -33°	1·458—1·467		Total menthol 50—65%; esters as menthyl acetate 6—14%
(3) Japanese *Mentha arvensis* (undementholised)	1—1·6		0·900—0·915	-30° to -42°	1·460—1·468		Total menthol 70—90% (45—60% in dementholised oil) esters as menthyl acetate 3—6%
Petit-grain oil *Orange twigs and shoots*	0·2—0·4						Found in S. France, Spain, Algeria.

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15°C.	Optical rotation at 20°C.	[Refr. index at 20°C.	One part soluble in parts alcohol.	Other data and information.
European		Limonene, linalol, geraniol.	0·888	−1° to −8°	1·462 −1·465	3 (70%)	Esters as linalyl acetate 50—80%
Paraguay		Pinene, dipentene, cymphene, terpineol and geraniol esters.	0·884 −0·895	−2° to +5°	1·462 −1·465	3 (80%)	Esters as linalyl acetate 35—65%
Pimento oil (Allspice) *Pimento officinalis* (fruit)	3—4·5	Eugenol (60—80%) and its methyl ether, cineole, phellandrene, caryophylene.	1·025 −1·055	0° to −5°	1·525 −1·535 (25°C.)	2 (70%)	Indigenous to West Indies
Pine needle oils *Pinus pumilio*		*l*-Phellandrene, sylvestrene, cadinene.	0·863 −0·875	−6° to −14°	1·474 −1·48	1½—2½ (95%)	5—7% esters; at least 85% over below 200°C.
Abies sibirica (fresh leaves and twigs)		Bornyl acetate, pinene, camphene, dipentene, phellandrene.	0·900 −0·930	−30° to −45°	1·470 −1·473	1 (90%)	Found in Russia. Bornyl acetate 30—46%; 90—95% over below 165°C.
Pinus sylvestris	0·4—0·6	*d*-Pinene.	0·868 −0·925	−22° to +7°	1·4735		Esters 2—11%.
Red thyme oil (See Thyme oil) Rose oil (Otto) *Rosa damascena* (flowers) Bulgarian	0·02 —0·03	Geraniol, citronellol, nerol, farnesol, phenyl ethyl alcohol and stearoptene (10—15%), M.P. 34°C.	0·850 −0·860 (30°C.)	−2° to −4° (25°C.)	1·460 −1·465 (25°C.)	1·5 (70%)	Found in Bulgaria. M.pt. after solidification 18—22°C.; citronellol 30—45%; total alcohols as geraniol 65—75%
Rose oil (French)			0·859 −0·874	−2° to −4° (25°C.)	1·460 −1·465 (25°C.)		Total alcohols 80—85%; citronellol 40—45%
Rose geranium oil *Pelargonium odoratinium* (leaves)	0·1—0·2	Geraniol and esters, citronellol, acetic, butyric, valerianic and tiglic acids.					Indigenous to South Africa. Cultivated in France, Spain, Algeria and Reunion (Bourbon)

Name and source	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation at 20° C.	[Refr. index]b at 20°C.	One part soluble in parts alcohol.	Other data and information.
French		Esters as geranyl tiglate (22—28%), alcohols as geraniol (75%), citro-nellol, (about 40%).	0·895 —0·905	−7° to −12°	1·461 —1·470	3 (70%)	Geranyl tiglate 20—30%.
Algerian			0·890 —0·904	−6° to −12°	1·465 —1·472	3 (70%)	Geranyl tiglate 16—29%; geraniol 75%; citronellol 33%
Bourbon Reunion			0·890 —0·896	−8° to −14°	1·461 —1·470	3 (70%)	Geranyl tiglate 20—34%; geraniol 80%; citronellol 40%
Spanish			0·886 —0·906	−7° to −11°	1·461 —1·470	3 (70%)	Geranyl tiglate 25—42%; geraniol 70%
Rosemary oil *Rosemarinus officinalis* (leaves)	1—2	Pinene, camphene, cineol, camphor, borneol, bornyl acetate.	0·895 —0·920	−2° to +15°	1·466 —1·472 (25°C.)	10 (80%)	Total alcohols as borneol 8—30%; esters as bornyl acetate 1—7%. M.pt. 9°—10°C.
Rue oil *Ruta graveolens* (herb)	0·06	Methyl nonyl ketone (90%), methyl-anthranilate.	0·830 —0·845	0° to +8°	1·430 —1·436	3 (70%)	
Sage oil *Salvia officinalis*	1·5—3	Pinene, cineol, borneol, salvone (thujone).	0·910 —0·932	+2° to +25°	1·457 —1·469	2 (80%)	Esters 2—6%; total alcohols 20—25%; salvone (thujone) 40—50%
Sandal wood oil *Santalum album* (wood)	2·5—6	Santalol (90—98%), sesquiterpenes and alcohols.	0·973 —0·985	−13° to −21°	1·500 —1·510	6 (70%)	Found in India. Sap. val. 5—20.
Sassafras oil *Sassafras officinale* (root and bark)	3—9	Safrol (80—90%), pinene, phellandrene, camphor (6%), eugenol, and cadinene.	1·065 —1·095	+1° to +4°	1·525 —1·530	2 (90%)	Found in N. America, Canada

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15° C.	Optical rotation information.	[Refr. index] at 20°C.	One part soluble in parts at 20° C.	Other data and alcohol.
Savin oil *Juniperus sabina*	3—5	Pinene, sabinene, sabinol (free, 10%), sabinyl acetate (36—55%). Linalol.	0·910 —0·930	+40° to +60°	1·472 —1·477	15 (80%)	A Japanese oil; total alcohols 65 90%
Shiu oil			0·870 —0·895	-1° to -16°	1·4606 —1·480 (25°C.)	1—1·5 (80%)	Found in America and Germany
Spearmint oil, *Mentha viridis, M. Crispa* (fresh herb)	0·3	Carvone (35—66%), limonene, pinene, and esters.	0·920 —0·940	-30° to -53°	—1·489 (25°C.)		
Spike Lavender oil (See Lavender oil)							
Star anise oil (See Anise oils)							
Sweet Birch oil (Oil of winter-green) *Betula lenta* (bark, etc.)	0·5—0·7	Methyl salicylate (99%).	1·180 —1·187	Inactive	1·534 —1·537	5—8 (70%)	Indigenous to S. Canada and Northern U.S.A.
Tansy oil *Tanacetum vulgare* (herb)	0·1—0·2	Thujone (tanacetone), *l*-camphor, borneol.	0·925 —0·955	+25° to +45°	1·457 —1·460	4 (70%)	
Tarragon oil (Estragon oil) *Artemisia dracunculus*		Estragol (methyl chavicol), phellandrene.	0·890 —0·960	+2° to +9°	1·516 —1·578	10 (80%)	Indigenous to Siberia
Thyme oils Red Thyme oil *Thymus-vulgaris* (herb)		Thymol, carvacrol, cymene, *l*-pinene, borneol, linalol.	0·905 —0·930	0° to -4°	1·480 —1·498	2 (80%)	Found in S. France Phenol content 20—50%
Lemon Thyme *Thymus hyemalis*		Carvacrol, citral (10%).	0·900 —0·920		1·465 —1·480		Spanish; phenol content 8—12% distills 80—85% 155—165°C.;
Turpentine oils Species of Pinus American *Pinus australis* (*Pinus palustris, P. taeda*)		*d*- or *l*-pinene.	0·855 —0·877 0·862 —0·870		1·468 —1·473	5—8 (70%)	Iodine value 360—375 (Wijs) 95% below 170°C.

Name and source.	Yield per cent.	Constituents.	Sp. Gr. at 15°C.	Optical rotation at 20°C.	Refr. index at 20°C.	One part soluble in parts alcohol.	Other data and information.
French	15—16		0·855 —0·874	—18° to —40°	1·470 —1·480	5—8 (70%)	75—90% distills 155—165°C.;
Pinus maritima Russian and			0·855 —0·874	+5° to +16°	1·479		30—70% distils 155—165°C. ;
Swedish							
Pinus sylvestris Wood turpentine (Yellow pine oil) (Stumps of felled trees)		Total alcohols (50%), terpineol, borneol, iso-fenchyl alcohol, pinene, camphene, etc.	0·953	—3°		3 (80%)	
Verbena oil (true Vervain oil) *Verbena officinalis, V. triphylla*		Citral (20—38%), linonene, geraniol.	0·900 —0·926	—8° to —16°			Found in France and Spain.
Vetivert oil *Vetivera zizanoides* (dried root)	0·4—1·0	Sesquiterpenes.	0·982 —1·042	+10° to +40°	1·515 —1·530	3 (80%)	Found in Mysore, Bengal, Burma, Reunion.
Wintergreen oil (See Sweet birch oil)							
Wormseed oil (1) American *Chenopodium ambrosioides*	0·6—1	Paracymene (20%), ascaridol (60—65%), vestrene, camphor.	0·950 —0·990	—5° to —10°	1·466 —1·476	4—10 (70%)	Chenopodium oil Sap. val. 246—280
(2) European *Artemisia maritima*	2	Thujone, cineol, dipentene, terpinene, terpineol.	0·915 —0·940	0° to —5°			
Wormwood oil *Artemisia Absinthe oil absinthium* (herb)	0·2—0·97	Thujone, thuiyl alcohol esters of acetic, iso-valeric, and palmitic acids, pinene.	0·925 —0·955	Dextro	1·460 —1·474	2—4 (80%)	Found in Africe, Europe, N. Asia.
Ylang Ylang oil *Cananga odorata* (flowers) (See Cananga oil)	1·5—2	Esters of benzoic and acetic acids, alcohols, phenols, and sesquiterpenes.	0·930 —0·967	—38° to —65°	1·480 —1·515	1—2 (95%)	Sap. val. 95—160.

PAINTS AND PIGMENTS.

Analysis of Pigments.

WHITE PIGMENTS.

White lead. When pure, this has a composition approximating to $2PbCO_3.Pb(OH)_2$. The following determinations are carried out :

Moisture, by heating at 105°C. Water of combination is usually determined by difference ; it may be estimated by heating at 150°C. for 6—8 hours, but the result is usually high owing to loss of carbon dioxide.

Total lead is determined either (i) volumetrically or (ii) gravimetrically.

(i) About 0·5 grm. of the white lead is dissolved in nitric acid, excess ammonia is added, and the solution made distinctly acid with acetic acid. It is then boiled, and sufficient standard potassium dichromate added to precipitate almost the whole of the lead. The solution is boiled until the precipitate changes in colour from yellow to orange, and whilst still boiling, the titration is completed, using a $2\frac{1}{2}\%$ solution of silver nitrate as external indicator. The dichromate is usually of such a strength that 1 cc. = ·01 grm. Pb, and is standardised against pure lead.

(ii) About 1 grm. of the white lead is moistened with water, dissolved in acetic acid, filtered and washed. The residue is ignited, and weighed as impurity ($BaSO_4$, etc.). The filtrate is treated with sulphuric acid, and evaporated until all acetic acid has been removed, and further until white fumes are evolved. The total lead is then estimated as sulphate in the usual manner.

Sulphate is estimated by dissolving a quantity of the white lead in a slight excess of hydrochloric acid, diluting to 200 cc., and filtering. The lead is deposited by means of aluminium foil held on the bottom of the beaker whilst the solution is gently boiled. The solution is filtered, the filtrate oxidised with a few drops of bromine water, boiled to expel excess of bromine, and the sulphate present is then precipitated as $BaSO_4$ and is calculated to $PbSO_4$.

Carbonate. Carbon dioxide is liberated from the pigment either by heating alone or with hydrochloric acid, and is dried, collected in caustic potash, and weighed. The carbon dioxide is calculated to $PbCO_3$, and this, together with the $PbSO_4$, is deducted from the total Pb, the remainder being calculated to $Pb(OH)_2$.

Acetic acid is an objectionable impurity, which it is sometimes necessary to estimate.

To 18 grm. of white lead, contained in a 500 cc. flask fitted for steam distillation, are added 40 grm. syrupy phosphoric acid, 18 grm. zinc dust, and 50 cc. water, and the mixture is distilled to a small bulk by direct heat. Steam is passed in until the flask is half full of condensed water, and the contents of the flask are again distilled to small bulk. This operation is repeated, and the distillate is transferred to another flask, made slightly acid with 1 cc. of phosphoric acid and distilled to small bulk. Steam is passed in and the distillation continued as before, the process being repeated until the distillate is no longer acid. The distillate is titrated, either in bulk or as each 200 cc. distils over, with N/10 alkali, using phenolphthalein as indicator.

Zinc-lead pigments. These pigments are made by "subliming" the various grades of zinc-lead ores. The usual names and approximate compositions are :—

	% $PbSO_4$.	% PbO.	% ZnO.	% $ZnSO_4$.
Sublimed white lead	75—80	15—20	5	—
Zinc lead white......	50	—	50	—
Leaded zinc white...	20—25	—	70—75	<1.5

The following determinations are made :—
Moisture at 105°C.
Soluble sulphate. The pigment is boiled with aqueous alcohol (3 : 1), filtered, washed, the filtrate boiled to remove alcohol, and the sulphate determined, and calculated to $ZnSO_4$.
Total sulphate. The pigment is dissolved in hydrochloric acid, filtered, and sulphate estimated in the filtrate. If much lead is present the estimation is conducted as under "White lead." The sulphate found as $ZnSO_4$ above is deducted from this value, and the remainder calculated to $PbSO_4$.
Lead oxide. Total lead is determined as under "White lead," the lead found as $PbSO_4$ is deducted from this, and the remainder calculated to PbO.
Zinc oxide. The filtrate from the preceding determination is neutralised with ammonia, 3–5 cc. concentrated hydrochloric acid added, and the zinc estimated volumetrically by means of potassium ferrocyanide solution (see "Volumetric Analysis" Section).
From the amount of zinc found by this test, the Zn present as $ZnSO_4$ is deducted and the remainder calculated to ZnO.

Zinc oxide. Moisture at 105°C.
Soluble sulphate. About 10 grm. of the zinc oxide are extracted with boiling water, filtered, and the sulphate

estimated gravimetrically, or the zinc volumetrically, and calculated to $ZnSO_4$.

Total sulphate is determined as under " Zinc-lead pigments." Total sulphate—soluble sulphate = lead sulphate.

Lead is determined by dissolving in nitric acid, and precipitating lead as sulphate. It may also be determined by precipitating the lead from a slightly acid solution by means of sulphuretted hydrogen, dissolving the lead sulphide in nitric acid, and estimating the lead volumetrically. From the amount of lead found in this test, the lead found as lead sulphate is deducted, and the remainder calculated to PbO.

Zinc is determined volumetrically in 0·3 grm. sample dissolved in 8–10 cc. of hydrochloric acid. The zinc present as sulphate is deducted from this value, and the remainder stated as ZnO.

Sulphur dioxide is an objectionable impurity which sometimes has to be estimated. 3 grm. sample is mixed with 100 cc. recently boiled and cooled water, and 5 cc. concentrated sulphuric acid added. This is stirred until the solid has dissolved, allowed to stand for 15 minutes, and the sulphur dioxide is determined by means of $N/100$ iodine solution, using starch solution as indicator.

1 cc. $N/100$ iodine solution = 0·00032 grm. SO_2.

Arsenic and antimony may be estimated by the ordinary analytical methods.

Lithopone. Lithopone usually has a composition approximating to :—ZnS, 27–28 % ; $BaSO_4$, 70–71 % ; ZnO, 1–1·5 %.

The following determinations are usually made :—

Moisture at 105 °C.

Barium sulphate. 1·5 grm. of the sample are boiled with 10 cc. hydrochloric acid and water, and filtered. The residue is washed, and weighed as $BaSO_4$. This may contain silica or clay (see " Analysis of Barytes ").

Zinc. The total zinc may be estimated volumetrically in the filtrate from preceding test.

Zinc oxide. 1·5 grm. of the sample are digested for one hour with excess cold 5 % acetic acid (about 100 cc. is usually required), the insoluble matter is filtered off and washed, and zinc is estimated volumetrically in the filtrate (after boiling with hydrochloric acid to free from acetic acid), and calculated to ZnO.

Zinc sulphide. The insoluble matter from the previous test is boiled with 10 cc. of hydrochloric acid, and zinc is estimated volumetrically and calculated to ZnS.

An alternative method of analysis is to oxidise the lithopone with hydrochloric and nitric acids, and weigh the residue as

$BaSO_4$. The sulphate in the filtrate is then estimated, and calculated to ZnS. In the resulting filtrate the total zinc is estimated, and from this is subtracted the zinc found as ZnS, the remainder being calculated to ZnO.

INERT PIGMENTS.

The analysis of the inert pigments presents no special difficulties, and may be dealt with according to the usual methods. The following outlines are suggested :—

Barytes, Blanc fixe, $BaSO_4$. Estimations are made of moisture, loss on ignition, soluble and insoluble in hydrochloric acid (1 : 1). The insoluble matter contains the barium sulphate, together with any silica or silicates, and is therefore fused with fusion mixture and the melt extracted with water and filtered, the residue being washed until free from sulphate. In the filtrate silica, sulphate, alumina and magnesia are estimated. The residue is dissolved in dilute hydrochloric acid (if much silica is present, a portion of it will be present here and must be estimated), and iron, barium, and calcium estimated. If barium is in excess of sulphate, barium carbonate is present, or *vice versâ*, other sulphates are present. The magnesia and alumina represent asbestine and kaolin (see later), and any excess silica is free silica. Calcium is calculated to sulphate. If any carbonate is present, it is calculated as CO_2, unless there is no doubt as to whether it is barium or calcium carbonate. In case only barium sulphate and silica are present, the latter may be removed by means of hydrofluoric acid.

Calcium pigments. Paris white, Whiting, Gypsum. Estimations are made of the moisture, loss on ignition, carbonate, insoluble in dilute hydrochloric acid (barium sulphate and silica), and soluble in dilute hydrochloric acid (iron, alumina, calcium, magnesium, and sulphate).

Magnesium is calculated to sulphate (in gypsum) or to carbonate (in carbonates), the remaining sulphate and carbonate to $CaSO_4$ and $CaCO_3$. Loss on ignition *minus* carbon dioxide equals combined water.

Kaolin (aluminium silicate). The material is fused with alkali carbonates, and in the melt estimations are made of silica, iron *plus* alumina (gravimetrically), iron (volumetrically), and calcium.

Calcium is calculated to carbonate if carbon dioxide is present, otherwise to oxide.

Asbestine (magnesium silicate). This is fused with alkali carbonates, and in the melt are estimated silica, iron and alumina, magnesium, and oxides of potassium and sodium.

Silica. This is examined as for insoluble matter under " Barytes."

RED PIGMENTS.

Iron oxide pigments include :—

Indian red, which is practically pure ferric oxide, with a small amount of insoluble matter, moisture, and combined water.

Tuscan red, which contains 40—60% ferric oxide, insoluble calcium salts, water, etc. It is sometimse "brightened" by precipitating upon it an organic red dyestuff.

Venetian red, which contains over 70% of ferric oxide, together with insoluble calcium and magnesium salts.

Ochres, which, although different in colour, have a composition somewhat similar to the above. They contain about 50—60% silica, 20—25% ferric oxide, 10—15% alumina, and water.

The following determinations are carried out :—

Moisture at 105°C.

Combined water. The residue from the previous test is transferred to a platinum crucible and heated on the blow-pipe to constant weight.

Silica and barium sulphate. The sample is fused with potassium bisulphate, and the melt extracted with water containing a small amount of hydrochloric acid. The insoluble matter is usually silica, but may also contain barium sulphate, and should be treated as under "Barytes."

Iron. The acid solution from the previous test is diluted to a known volume, sufficiently large to keep calcium sulphate in solution, and an aliquot portion titrated for iron, which is expressed as Fe_2O_3.

Alumina. Ferric and aluminium oxides are estimated together in the usual manner in another portion of the sample. From this the amount of Fe_2O_3 found in previous test is subtracted, and the remainder expressed as Al_2O_3.

In the filtrate from the alumina test, calcium, magnesium, and sulphate are estimated, and returned as CaO, MgO, and SO_3.

Carbon dioxide is estimated in the original sample, if necessary, and is deducted from the loss on ignition, and the remainder expressed as combined water *plus* organic matter.

Red lead and *Orange mineral*, approximately Pb_3O_4.

The following determinations are made :—

Moisture at 105°C.

Total lead. The sample is dissolved in nitric acid, and the lead estimated either as sulphate or volumetrically. In an impure sample, the acid solution is neutralised with ammonia, made faintly acid with hydrochloric acid, and the lead precipitated as sulphide. This is filtered off, washed, dissolved in nitric acid, and the lead estimated as above.

Lead dioxide. 0·5 grm. of the sample are mixed with a solution of 15 grm. sodium acetate crystals and 1·2 grm. potassium iodide in 5 cc. water and 5 cc. 50% acetic acid, and well shaken until all the red lead has dissolved. 15 cc. water are added, and the solution titrated with N/10 thiosulphate, using starch solution as indicator.

1 cc. N/10 thiosulphate = 0·011955 grm. PbO_2.

An alternative method is to triturate 2 grm. of the pigment with 2·5 grm. of ferrous ammonium sulphate, and brush into a beaker. 10—15 grm. ammonium chloride, and 60—80 cc. hydrochloric acid (1 : 1) are added, the mixture warmed, and excess ferrous iron titrated with N/10 potassium dichromate solution, using potassium ferricyanide as external indicator.

1 cc. N/10 dichromate = 0·011955 grm. PbO_2.

Organic matter is usually determined by difference.

Vermilion (mercury sulphide). As a pure pigment this is very expensive, and is rarely used, but it has been largely adulterated and imitated.

2 grm. pigment are ignited to constant weight in a porcelain crucible in a draught chamber. The ash should not exceed 0·5%.

Mercury may be estimated, if necessary, by the usual methods.

Adulterants and substitutes (vermilionette, etc.). These are usually organic reds on a basis of red lead, zinc oxide, barytes, etc., which may be analysed as usual, estimating organic matter by difference.

The colours mostly used are Paranitraniline red, Alizarin, Eosin, Scarlet 2R, etc., which may be detected qualitatively (see "Identification of Dyestuffs" Section).

BROWN PIGMENTS.

Vandyke brown. This pigment usually contains about 90% organic matter and water, the remaining ash containing silica, iron, alumina, calcium, etc., which are estimated as under "Iron oxide reds."

Umbers and Siennas. Umbers usually contain varying proportions of combined water, silica, and ferric oxide, together with a small amount of moisture, alumina, calcium, manganese, and magnesium salts. Siennas contain varying proportions of combined water, silica, ferric oxide, and manganese dioxide, together with a small amount of moisture, aluminium, calcium and magnesium salts.

The following determinations are made :—

Moisture, combined water, barium sulphate and silica, ferric oxide, alumina, calcium oxide, magnesium oxide, and sulphate, as under "Iron oxide reds."

Manganese. A convenient weight of the sample is dissolved in the least possible amount of boiling strong hydrochloric acid, dilute sulphuric acid added, and the solution boiled until white fumes are evolved. The residue is taken up with water, and transferred to a measuring flask. Zinc oxide is added in excess in the form of a paste until all iron present is precipitated. The mixture is made up to volume, allowed to settle, and an aliquot portion treated with bromine to precipitate manganese. The precipitate is filtered off, washed, ignited, and weighed as Mn_3O_4, being calculated as MnO_2.

BLUE PIGMENTS.

Prussian blue, Antwerp blue, Chinese blue, Turnbull's blue, etc. All blues of this class are iron, or double iron and sodium, or potassium, salts of hydroferro- or hydroferri-cyanic acids.

The following determinations are made :—

Moisture at 105°C.

Insoluble matter. 1 grm. of pigment is ignited at a low temperature until it is completely decomposed. The residue is digested with hydrochloric acid, evaporated almost to dryness, diluted, filtered and the insoluble matter, probably consisting of barium sulphate, silica, etc., weighed.

Iron is estimated volumetrically in an aliquot portion of the filtrate from the previous test, as stated under "Red pigments.

Sodium or potassium. In another portion of the filtrate from the 'insoluble matter' test, iron, aluminium, and calcium oxides are removed and estimated. The filtrate is then acidified with hydrochloric acid and evaporated to dryness to remove ammonium salts, and the residue weighed as alkali salts. This residue is dissolved in water, made up to known volume, and chloride and sulphate are estimated in aliquot portions of the solution.

Chloride is calculated to Na_2O or K_2O (whichever is found by qualitative tests) as combined alkali in the pigment. Sulphate is calculated to Na_2SO_4 or K_2SO_4 as impurity.

Total nitrogen is determined by the Kjeldahl-Gunning method on 1 grm. of sample. The percentage of nitrogen is multiplied by 1·86 to give percentage of CN, and the result is expressed as such.

The complete estimation of these blues is seldom required. Usually it is assumed that

% iron × 3·03 = % Prussian blue,

or, more usually, % nitrogen × 4·4 = % Prussian blue.

and N × 1·857 = CN.

Ultramarine is probably a complex silicate and sulphide of

soda and alumina. The full chemical analysis is rarely required, but the following determinations may be made :—

Silica. A convenient weight of the sample is digested with hydrochloric acid, evaporated to dryness, and baked for two hours. The process is repeated, the residue extracted with hydrochloric acid, filtered, and the insoluble matter weighed as silica. It should, however, be tested for barium sulphate, and this, if present, should be estimated as under " Barytes."

Aluminium is precipitated as hydroxide from the filtrate from the silica test. The precipitate is washed, ignited, and weighed as Al_2O_3. In presence of iron, the precipitate is redissolved, and the iron estimated volumetrically.

Sodium. The filtrate from the aluminium test is acidified with sulphuric acid, evaporated to dryness, and the residue ignited, and weighed as Na_2SO_4. The result is stated as Na_2O.

Total sulphur. 1 grm. of sample is fused with 4 grm. sodium carbonate and 4 grm. sodium peroxide in a nickel crucible. The melt is extracted with water, acidified, filtered, and sulphate estimated in the filtrate.

Sulphate. 1 grm. of sample is treated with hydrochloric acid to remove silica, and sulphate is estimated in the filtrate. This value is deducted from the total sulphate found above, and the remainder is calculated to sulphide.

Cobalt blue or *Thénard's blue*, which approximates to $CoO.Al_2O_3$.

Smalt, which is cobalt potassium silicate.

YELLOW PIGMENTS.

Chrome yellows. These colours, including lemon and canary yellows, consist essentially of lead chromate. The lighter shades contain lead sulphate, whilst the darker shades, including scarlet chrome, chrome red, Chinese red, vermilion substitute, and American vermilion, are probably basic chromates.

The following determinations are carried out :—

Moisture at 105° C.

Insoluble matter. 1 grm. sample is dissolved in strong hydrochloric acid, the solution diluted and filtered. The residue is washed, ignited, and weighed as insoluble matter. It should be examined for barium sulphate and silica.

Lead. The filtrate from the previous test is neutralised with ammonia, acidified with hydrochloric acid, and the lead precipitated as sulphide. The precipitate is dissolved in nitric acid, and the lead determined gravimetrically as $PbSO_4$.

Chromium may be estimated in the combined filtrates from PbS and PbSO$_4$ in previous test either gravimetrically or volumetrically. In each case the chromate is calculated to PbCrO$_4$.

Lead sulphate is estimated in 1 grm. of the original sample, as under "White lead."

In the absence of calcium, SO$_3$ is calculated to PbSO$_4$, and the lead present as PbSO$_4$ and PbCrO$_4$ is deducted from total lead, the remainder being calculated to PbO. In presence of calcium, any carbon dioxide present is calculated to CaCO$_3$, the remaining calcium being calculated to CaSO$_4$.2H$_2$O. The SO$_3$ present in this must be deducted from total SO$_3$ before PbSO$_4$ is calculated.

Zinc yellow is usually zinc chromate containing a varying amount of zinc oxide. The following determinations are made :—

Moisture at 105°C.

Insoluble matter. The pigment is dissolved in an excess of cold strong ammonia, and the solution diluted and filtered. The insoluble matter is dried, weighed, and then extracted with hydrochloric acid and examined for the usual adulterants.

Zinc and Chromium. The filtrate from the previous test is boiled with excess of concentrated hydrochloric acid until the colour is completely changed to green. The chromium is then precipitated by means of ammonia, and zinc estimated volumetrically in the filtrate.

Chromium is calculated to ZnCrO$_4$, and the remaining zinc to ZnO.

Green Pigments.

The green pigments in most common use are what are known as "compound greens," *i.e.* mixtures of yellow and blue pigments, the chief one being

Chrome green. This is a mixture of Prussian blue and lead chromate, either prepared separately and mixed in the dry state, or precipitated together. The following determinations are made :—

Moisture at 105°C.

Insoluble impurities. A weighed quantity of the pigment is ignited gently in a platinum crucible at a dull red heat, until all the blue is decomposed. The residue is treated with hydrochloric acid, and allowed to digest on the steam bath for an hour. The solution is then diluted and filtered, the precipitate being washed, ignited, and weighed as "Insoluble impurities." It consists usually of barium sulphate, clay, and silicates, which may be identified and estimated if necessary.

Lead is precipitated as sulphide from the filtrate from the

previous test. The lead sulphide is dissolved in nitric acid, and the lead estimated as sulphate.

Iron, aluminium, and chromium. The filtrate from the lead sulphide in the previous test is boiled until free from hydrogen sulphide, and made to known volume. To an aliquot portion of this, ammonia is added, and the precipitate is filtered off, washed, ignited and weighed. This is total Fe_2O_3, Al_2O_3 and Cr_2O_3. The precipitate is dissolved in acid, the iron reduced, and estimated volumetrically, being calculated to Fe_2O_3. In absence of aluminium, this may be subtracted from the weight of precipitate above to give Cr_2O_3. If aluminium is present, chromium must be estimated volumetrically as under "Chrome yellow," and this, together with iron found volumetrically, is subtracted from the weight of precipitate above to give the amount of Al_2O_3. Cr_2O_3 should be calculated to $PbCrO_4$.

Sulphate. A portion of the sample is ignited and extracted with hydrochloric acid. Lead is removed as under "White lead," and iron by means of ammonia. The solution is then acidified, and sulphate estimated as usual, and calculated to $PbSO_4$. Any Pb in excess of $PbCrO_4$ and $PbSO_4$ is calculated to PbO.

Prussian blue is either calculated from the iron found as above, or from nitrogen estimated by the Kjeldahl method.

Another compound green is a mixture of zinc yellow and Prussian blue or ultramarine, which are estimated as below.

Zinc yellow is extracted with ammonia, and either the loss taken as zinc yellow, or the extract estimated as under "Zinc yellow." Prussian blue is estimated as under "Chrome green."

Ultramarine. The insoluble is probably a mixture of ultramarine and impurities. The ultramarine cannot be estimated directly, but may be approximated by comparison with a standard ultramarine, and the residual impurity assumed to be some inert pigment, e.g. $BaSO_4$.

Guignet's green is a hydrated sesquioxide of chromium, which frequently contains boric acid. The water may be estimated at above 200° C. Adulteration is rare, so that full analysis is rarely required. The pigment dissolves only in concentrated hydrochloric acid on prolonged boiling, and impurities soluble in dilute hydrochloric acid may be estimated by extraction. Barium sulphate. etc., are estimated by fusing with 5–6 times the weight of a mixture of equal parts of sodium carbonate and peroxide and proceeding as under "Barytes," estimating the chromium volumetrically in an aliquot portion of the aqueous extract.

The other chromium oxide greens are practically pure Cr_2O_3, and may be examined as above.

The copper and copper-arsenic greens are very rarely, if at all, used in paint manufacture. *Rinmann's green* or *Cobalt green*, a compound of oxides of cobalt and zinc, is, however, sometimes met with.

BLACK PIGMENTS.

The essential constituent of all black pigments is carbon, either (1) natural as graphite, or (2) produced by burning oil or natural gas to give lamp black or vegetable blacks, or (3) by calcining matter such as bone ivory or refuse.

The following determinations are made :

Moisture at 105° C., and

Ash on 2 grm. of sample, as described in " Coal analysis " section.

Carbon is usually determined by difference : moisture *plus* ash (*plus* oil) from 100 per cent.

In some cases, further examination is necessary to classify the black, *e.g.* in the second class mentioned above, some oily matter is usually present, and the third class is distinguished by the ash.

Oil may be estimated by heating 2 grm. of the dry pigment to dull red heat in a platinum crucible with lid, cooling, and weighing the loss as volatile matter or oil. The residue may then be further heated to ash. The oil may also be extracted from 2 grm. of sample with ether in a suitable extraction apparatus.

Ash may be digested with *aqua regia*, diluted and filtered. The solid matter is washed, ignited, and weighed as insoluble matter. If this is high, it may be further examined for presence of silica, barium sulphate and clay as adulterants. The filtrate from the insoluble matter is made to known volume, and in an aliquot portion, calcium and magnesium (and iron, if necessary) are estimated. In another aliquot portion, the phosphoric acid is precipitated by means of ammonium molybdate, the precipitate dissolved from the filter paper with hot dilute ammonia, and the phosphate estimated in the solution as magnesium pyrophosphate.

Magnesium is calculated to phosphate, the remaining phosphoric acid to calcium phosphate, and the remaining calcium to carbonate.

PHYSICAL TESTS.

Colour. Equal weights of the sample and a standard pigment are placed with an equal number of drops of bleached linseed oil on a large glass plate, and thoroughly rubbed out by means of a suitable spatula. The pigments (in oil) are

transferred on to a glass slide and spread evenly at equal thickness, the standard and the sample side by side, so that one edge of the standard touches one of the sample, and the colour judged from both sides of the slide. During this "rubbing out" process a good idea is obtained of the "fineness" of the sample, compared with a standard sample.

Body or opacity of white (base) pigments. This is the same operation as the colour test, but equal weights of a sample of ultramarine are added to each (e.g. 1 grm. white, 50 mgrm. blue). By comparing the shades of blue obtained, the weaker shade will indicate the stronger white pigment.

A more definite idea of the strength of a pigment may be obtained by rubbing out the standard as above, and additions from a known weight of the sample are made to an amount of blue equal to that in the standard, until the same shade of blue is obtained. The weight of the pigment under examination necessary for this is noted. The method of stating the result varies, but the most usual is as follows :—

    100 parts standard correspond to 90 parts sample ; sample is 10% strong :

    100 parts standard correspond to 110 parts sample ; sample is 10% weak.

Tinting strength of colours is the converse of the previous test. Equal weights of the same sample of a (base) white pigment (usually zinc oxide) are taken together with equal quantities of linseed oil, and to one is added a certain weight of a standard colour, and to the other an equal weight of the colour under examination, the last weights depending upon the strength of the colour. The colours are treated as in the previous tests, but in this case the stronger shade indicates the stronger colour. A definite ratio of the strengths of the colours may be obtained in a like manner to the previous test, noting the weights of white pigment used to equal weights of the colour, and stating the results as follows :—

    Standard required 100 parts, sample required 90 parts, ZnO ; sample is 10% weak :

    Standard required 100 parts, sample required 110 parts, ZnO ; sample is 10% strong.

Paint Materials.

Linseed oil.

Comparisons of the colour, odour, taste, turbidity, separation of sediment on standing, and time of drying are usually made against a standard sample.

Time of drying. This may be carried out roughly by coating two glass plates, $3'' \times 4''$, one with the oil under

examination, and the other with the standard. The plates are exposed to air and light at the ordinary temperature, and the time is noted when one ceases to be tacky to the touch, as compared with the other.

A more accurate method is to weigh out about 5 grm. of litharge on a tared flat aluminium or glass dish. 0·5 to 0·9 grm. of the sample is dropped on to the litharge, keeping each drop separate, and the dish, etc., weighed again. The dish is then exposed to air and light, but kept free from dust, for 48 hours, when it is re-weighed, and the amount of oxygen absorbed is calculated as percentage on the original weight of oil. The test may also be carried out without regard to time by comparison with a standard sample.

For still more accurate results, the oil is dried on spongy lead, prepared by the action of granulated zinc on lead acetate and subsequent washing with absolute alcohol.

The value given by this test is usually about 16%, slightly lower in the case of boiled oils.

The following tests are essential :—

Specific gravity at 15·5°C., by Westphal balance, should be 0·932—0·938. A low value indicates the presence of fatty or mineral oils, a high value indicates resin oils, as adulterants.

Moisture is determined by heating 5 grm. of oil in an air oven at 105°C. for 45 minutes.

Unsaponifiable matter is determined as under " Oils and Fats," but petroleum ether is generally used for extraction. This figure should be below 1·5% for raw oils, and below 2·5% for boiled oils.

Saponification value, as under " Oils and Fats." The figure should be 189 to 192.

Iodine value, as under " Oils and Fats," using Hanus' solution. The value should be 178 to 190.

Acid value. 10 grm. of the oil are boiled for half an hour with 50 cc. alcohol, cooled, and titrated with decinormal caustic soda. The figure should be less than 6·0.

Flash point. Generally the " open " flash point is required on linseed oils, principally by railway and steamship companies.

A nickel crucible, 60 mm. diameter at the top, 40 mm. at the bottom, and 60 mm. in height, is placed in a hole in the centre of an asbestos board 200 mm. square, so that the bottom of the crucible projects about 25 mm. through the asbestos. A thermometer, reading to 400°C., is suspended above the centre of the crucible, so that the lower end is 10 mm. from the bottom of the crucible. The oil under examination is then poured into the crucible to a depth of 45 mm. The crucible

is heated by a Bunsen burner, so arranged that the rise in temperature of the oil is 9°C. per minute. A gas jet, 6 mm. long, from a mouth blowpipe is used as a test flame. The testing is commenced when the oil reaches 220°C., and is continued at every rise of 3°C., the flame being moved slowly across the entire width of the crucible, immediately in front of the thermometer, and 10 mm. above the surface of the oil. The flash point is the lowest temperature at which the vapours above the oil flash and then go out.

The following tests are optional :—

Fire point. This is a continuation of the flash point test. The heating is continued until the vapours catch fire and burn over the surface of the oil.

Viscosity, as in the "Liquid fuels" section, usually at 20°C.

Ash on 20 grm. of sample. This should be below 0·2%.

Refractive index, as in the "Oils and Fats" section.

Free mineral acid, as in the "Oils and Fats" section.

Detection of cottonseed oil, by the magenta test, as in the "Oils and Fats" section.

Detection of mineral oil, as in the "Oils and Fats" section. This will also be indicated by a high value for unsaponifiable matter.

Detection of resin or resin oil by the Liebermann-Storch reaction, as in the "Soap Analysis" section.

Turpentine.

The following tests are carried out :—

Specific gravity should be 0·862—0·875 at 15·5°C.

Refractive index should be 1·469—1·474 at 20°C.

Flash point; the "closed" flash point is required, generally the standard Able apparatus is used. The test is commenced at 37°C., and continued at every $\frac{1}{2}$°C. The flash point should not be below 40·5°C.

The remaining tests are performed in comparison with a standard sample tested under similar conditions.

Colour and Odour.

Distillation. 100 cc. are distilled by direct heat, and the initial boiling point and the boiling point at each 10 cc. noted. Steam distillation may be used, the flask being heated to 80°C., steam passed in, and each 100 cc. of distillate collected separately and allowed to stand. The boiling point is noted for each fraction, and also the volume of turpentine in each 100 cc. of distillate.

Residue on evaporation. This test is carried out on the water-bath; the residue should not exceed 2·0%.

Sulphuric acid test. 6 cc. of the sample are taken in a thin-walled, stoppered glass tube, graduated to 30 cc. in tenths.

20 cc. sulphuric acid (4 parts concentrated H_2SO_4 to 1 part fuming H_2SO_4) are added, the tube being then shaken, cooled, and allowed to stand. At intervals the volume of the undissolved layer of oil is noted, and compared with the standard. After each reading the tube is well shaken.

If any adulterants are suspected, the specific gravity and refractive index of each fraction of the distillate should be taken, and a portion of each fraction tested for rosin spirits, which will be detected more readily in the first fractions than in the original turpentine. Wood turpentine is indicated by more regular increases in specific gravity and refractive index, also by a high boiling point, and the specific gravity of the last two or three fractions. Turps substitute lowers the specific gravity and flash point, and increases the range of distillation.

Rosin spirits. The fractions are mixed with an equal volume of hydrochloric acid, and granulated zinc is added, when the development of a green colour indicates the presence of rosin spirit. An alternative test consists in mixing a few drops of the fraction with a solution of sulphur in carbon disulphide, and phenol in carbon tetrachloride. Bromine vapour is allowed to come into contact with the surface of this solution, when a green colour indicates rosin spirit.

Turps substitute. The following tests are made :—

Specific gravity should be 0·75—0·78.

Colour and Odour.

Closed flash point, as under "Turpentine"; generally about 40°C.

Evaporation, as under "Turpentine." This should leave no residue.

Distillation, as under "Turpentine." 75% should pass over between 150°C. and 200°C., and the remainder below 250°C.

The above tests should be compared with those on a standard sample.

Sulphur. 100 cc. of sample are boiled for an hour under a reflux condenser with 1 grm. of metallic sodium. The liquid is cooled, and water is added carefully to dissolve the sodium. The aqueous layer is separated, and to it is added a drop of sodium nitroprusside solution when a violet-blue colour indicates the presence of sulphur.

Benzene. The sample is mixed with 8 volumes of strong sulphuric acid, and 2 volumes of strong nitric acid, and gently heated for 10 minutes. A smell of "bitter almonds" indicates the presence of benzene in the original sample.

Analysis of Paints.

SEPARATION OF PIGMENT AND VEHICLE.

Extraction of vehicle.

(*a*) Quantitatively. A hardened filter-paper is folded cylindrically so as to fit into an extraction thimble, and the whole is dried and weighed. 10 to 15 grm. of the well-mixed paint are spread on the filter-paper, which is then folded, placed in the cylinder, and weighed again. The thimble is then transferred to a Soxhlet or other extraction apparatus, and extraction continued until the process is complete. The thimble is dried and weighed, when the loss in weight represents the amount of vehicle present. The solvent is usually ether, but if much water is present, acetone is preferable, and the water is then included in the loss in weight.

(*b*) Qualitatively. The amount of pigment from the previous test is generally sufficient for analysis, but larger quantities must be used to obtain an analysis of the vehicle. The separation may be carried out in bulk by placing a large quantity of the paint in a stoppered cylinder, and keeping at a constant temperature not exceeding 60°C. When a suitable quantity of vehicle has separated it may be removed by a syphon, or by suction. Bulk separation may also be effected by means of the centrifuge, *e.g.* the Babcock butter tester, the process being quicker if the chamber is heated to about 60°C. by means of steam.

After most of the vehicle has been removed, the residue is repeatedly mixed with a solvent in order to obtain the pigment free from vehicle; with sufficient care this operation may be made quantitative.

ANALYSIS OF THE VEHICLE.

Separation of the volatile oils, etc.

The volatile oils are separated either by direct or steam distillation, the latter being preferable. 100 grm. of the vehicle are weighed into a 500 cc. flask, fitted with an inlet for steam, and also with a condenser. The flask is heated to 100°C. in an oil bath, steam passed in, and the temperature gradually raised to 130°C. The distillation is continued

until the whole of the volatile oil is distilled. The distillate is allowed to stand, the water separated and its volume noted, and the oils are weighed. After allowing for the solubility of turpentine in water (0·3—0·4 cc. per 100 cc.), the volatile oil is calculated to percentage on the vehicle.

The residual oil is kept for further examination. In case the amount of vehicle is not sufficiently large to admit of steam distillation, it is placed in a suitable flask connected with a condenser, and distilled. The temperatures at which distillation commences, and of each fraction (10% of whole) are noted, but the distillation is not taken above 185°C. This gives an indication of the result which would be obtained if the volatile oil were re-distilled as noted below. The volatile oil is weighed off as before.

Analysis of the volatile oils. These will consist of turpentine, rosin spirit, turps substitute, benzol, etc., and may be examined as under "Turpentine" and "Turps substitute" as far as quantity will permit.

Analysis of the other oils. In better class paints the oil remaining after the steam distillation is linseed oil together with a solid drier. It is sometimes adulterated with one or more of the following :—Other drying and semi-drying oils, *e.g.* China-wood, corn, cottonseed, fish oils, etc. ; rosin and rosin oils ; mineral oils. It is examined as under "Linseed oil," with the following conclusions :—

Specific gravity : low, mineral oil or drying oils other than China-wood oil; high, rosin, etc., or excessive oxidation.

Unsaponifiable matter : high, incomplete separation of the volatile oil, *e.g.* last fraction (high B.P.) of a petroleum substitute.

Saponification value : high, cottonseed oil; low, corn oil.

Iodine value : abnormally high, presence of turpentine ; low, semi-drying oils. If Hanus method were used, China-wood oil would give a high value, whereas with Hübl's method a low value is obtained.

Ash : high, the presence of "driers" in the vehicle.

The ash will contain the bases of such driers, and may be examined for them, but in presence of lead, it is better mix some of the residual oil with turpentine or benzene, acidify, shake the extract with hot water, and examine the solution.

Rosin should be tested for qualitatively, and estimated as in the "Soap Analysis" section.

If the residual oil is from a direct distillation the results obtained by its examination are not very trustworthy. A better method is as follows:—The oil is saponified, and the unsaponifiable matter extracted as usual, when a high value would indicate presence of heavy petrol turpentine, containing a fraction above 185°C. The soap solution is acidified, and the fatty acids collected and dried, when they are examined for molecular weight and iodine values. They are also tested for presence of rosin and rosin oils.

Water is estimated in the original paint, as in the "Oils and Fats" section. 100 grm. of paint and 75—100 cc. of xylene are used, and the apparatus fitted up so that a slow current of air may be drawn through it during the later stages of the distillation. The presence of pigments containing combined water (e.g. white lead) causes inconsistent results. It is usual to deduct from the water found the combined water of any white lead present.

Analysis of the Pigment.

The pigment extracted from the paint is dried at 105°C., weighed, and is then ready for analysis as under "Pigments." The only difficulty lies in the possible combinations of pigments in one paint. The usual combinations are given below, together with the most complicated case, and suggestions for the analysis. The extreme case seldom occurs, and, on the results of a preliminary qualitative examination, the method of analysis may be arranged to suit the special case. For example, a white paint containing no zinc could only contain white lead and sublimed white lead, or if it contained no lead, only zinc oxide and lithopone could be present, with inert pigments in each case. Further, certain combinations are obviously improbable, e.g. lithopone and a lead pigment.

Loss on ignition. This test is usually applied to all pigments, and represents combined water, carbon dioxide, or other chemical loss (e.g. burning of ZnS to ZnO), and organic matter; the last-named may be some vehicle which has escaped extraction

The following are the pigments likely to be met with in the different colours of paint:—

White—all active and inert white pigments; also a small amount of blue, usually ultramarine.

Red—all red pigments; in darker shades alone, in lighter shades with a white base; blue (ultramarine), orange chromes, and black.

Brown—white base (as above); umbers; siennas; ochres; some reds and yellows; black.

Blue—white base; ultramarine or Prussian blue; greens and yellows.

Yellow—white base; chrome and zinc yellows; umbers; ochres; some blues and reds.

Green—white base; greens; some yellows or blues; ochres; siennas.

Grey to Black—white base; blacks; blues; reds; some ochres or yellows.

It will be seen that an accurate estimation of the various pigments in a coloured paint is difficult, if not impossible, so that the object of the analysis must be to obtain a fairly accurate idea of the proportions and compositions of the white base and the principal colours. The secondary colours and their proportions are found when matching the sample on a practical scale.

The following is a scheme for the analysis of the main constituents of a pigment extracted from a sample of paint :—

White. As the sublimed zinc-lead pigments occur very rarely in English practice, they are ignored at the commencement of the analysis.

The pigment is boiled with concentrated hydrochloric acid and filtered; it is noted whether any carbon dioxide or hydrogen sulphide is evolved. The insoluble matter may contain barium sulphate, silica, and aluminium or magnesium silicate. The insoluble is fused as usual, and examined for silica, sulphate, aluminium, barium (and calcium), and magnesium. In the filtrate, lead is estimated as sulphate; the filtrate made ammoniacal (to remove iron), made to known volume, and zinc precipitated with hydrogen sulphide. The precipitate is allowed to settle, and in a portion of the clear liquor calcium (and sometimes barium from the carbonate) is estimated. The precipitated zinc sulphide is dissolved in hydrochloric acid, and the zinc estimated volumetrically.

Carbon dioxide is estimated in the usual way on the original pigment, but in presence of zinc sulphide, a large excess of potassium dichromate must be mixed with the pigment before it is placed in the carbon dioxide generator. In the absence of calcium carbonate, carbon dioxide is calculated to white lead. If calcium carbonate is present a portion of the pigment is extracted three or four times with alcohol and nitric acid (1 part conc. HNO_3 to 9 parts alcohol by volume), stirring and allowing to settle each time. The extracts are

filtered, the calcium present estimated, and calculated to carbonate. Excess carbon dioxide is calculated to white lead; excess calcium is calculated to sulphate.

Zinc sulphate is estimated in the original pigment, as under "Zinc oxide," and zinc oxide as under "Lithopone" (acetic acid method).

Zinc found as sulphate and oxide is deducted from total zinc, and the remainder calculated to sulphide. If lead be present, sulphate is estimated in a hydrochloric acid extract of the pigment, as under "White lead"; otherwise, sulphate is estimated in the ordinary manner. From this value the sulphate present as zinc and calcium sulphates is deducted, and the remainder calculated to lead sulphate. The lead as sulphate and white lead is deducted from total lead, and if the remainder is considerable, and appreciable quantities of lead sulphate are present, it is calculated to PbO; otherwise it is calculated to $Pb(OH)_2$ and added to white lead, as variations in the composition of the latter are possible.

In the insoluble matter barium is calculated to sulphate, and the remainder stated as silica, alumina, lime and magnesia. Magnesia may be multiplied by 2·5 and stated as $MgO.SiO_2$, or may be multiplied by three and stated as asbestine (which allows for 3—5% combined water and impurities); alumina may be calculated to $Al_2O_3.2SiO_2.2H_2O$; and the remaining silica stated as free silica.

If the above analysis show the presence of the sublimed zinc-lead pigments (by high percentage of $ZnSO_4$, $PbSO_4$ and PbO), it may be augmented by the following tests :—

The pigment is boiled with a considerable excess of neutral ammonium chloride solution, filtered hot, and the precipitate washed with hot dilute ammonium chloride solution. In the filtrate lead, zinc, calcium, and sulphate are estimated. Calcium is calculated to sulphate, and the remaining SO_3 to lead sulphate. The remaining lead is calculated to PbO or $Pb(OH)_2$ (see above), and the zinc to oxide. The insoluble matter is treated as in the preceding estimation, lead being calculated to carbonate or white lead (see above), zinc to sulphide, and calcium to carbonate; other constituents as usual. The loss on ignition, *minus* any CO_2 found and any combined water in white lead (or in gypsum, $CaSO_4.2H_2O$, if present), is stated as "Organic matter."

Red. In addition to the above tests, the following are also carried out :—After lead has been removed, the solution is oxidised and iron and aluminium are precipitated as

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hydroxides, ignited and weighed. The precipitate is re-dissolved, and the iron estimated volumetrically, as under "Iron oxide reds." The filtrate, containing zinc, etc., is proceeded with as before.

If the presence of red lead is suspected, it is estimated as under "Red lead."

Carbon dioxide and any combined water (in white lead, gypsum, etc.) are deducted from the loss on ignition, and the remainder is still stated as "Combined water (in natural red oxide pigments) and Organic matter."

Brown. The only difficulty with a brown pigment is the manganese which contaminates the zinc sulphide precipitate, hence the latter is dissolved in caustic soda instead of hydrochloric acid, filtered, the filtrate acidified and zinc estimated as usual.

Manganese is estimated in the original pigment as under "Umbers and Siennas."

Blue. Prussian blue is insoluble in hydrochloric acid, and remains in the first insoluble matter. This is ignited to decompose all the Prussian blue, and the residue is boiled with hydrochloric acid until all the iron is dissolved. This is filtered, and the iron estimated in the filtrate and calculated to Prussian blue, or the Prussian blue may be calculated from a nitrogen determination on the orignal pigment, except in presence of organic nitrogen, *e.g.* from glue or casein in distempers.

A blue paint containing ultramarine will evolve hydrogen sulphide on dissolving in acid, and will also show itself by the presence of aluminium and silica. The quantity of ultramarine present cannot be definitely estimated, the figure usually given being the average of $SiO_2 \times 2.5$ and $Al_2O_3 \times 4$.

Yellow. The main difficulty with a yellow pigment is that it may contain iron, aluminium, and chromium together. The analysis may be carried out as under "Chrome green," or by the following method :—The precipitated hydroxides of iron, aluminium and chromium are dissolved in hydrochloric acid, re-precipitated with ammonia, and, without settling, sodium peroxide is added, and the beaker covered. When all the aluminium and chromium have passed into solution, the ferric hydroxide is filtered off, washed, ignited and weighed as Fe_2O_3 The filtrate is made to known volume, and one portion is acidified with acetic acid and the chromium estimated as lead chromate, or volumetrically. In the other portion, the aluminium and chromium are precipitated by acidifying with hydrochloric acid, and then adding ammonia. From this the

chromium found above (and calculated to Cr_2O_3) is subtracted, and the remainder is Al_2O_3. Preliminary inspection (*e.g.* blackening with ammonium sulphide) will indicate whether the chromium should be calculated to lead chromate or zinc chromate, and this lead or zinc must be taken into account when "placing" the total lead or zinc to the "base" white pigments.

Green. These colours are examined as under "Green pigments" (see also previous section).

A preliminary examination is of great assistance in identify ing a green colour; thus the colour blue is fairly stable to hydrochloric acid, and ultramarine is not; whilst the opposite is the case as regards heat. Also, an "ultramarine-chrome yellow" green is impossible, owing to the presence of sulphides in the ultramarine, and lead in the chrome yellow. In absence of chrome yellow and the corresponding blue, any chromium present is calculated to Cr_2O_3, and stated as such.

Black and Grey. When the proportion of coloured pigment to white base is small, the colour may be determined by difference. If it is large, the matter insoluble in hydrochloric acid is filtered through a tared filter, washed, dried, and weighed. It is then ignited and weighed, the loss being taken as organic matter (carbon, etc.). The presence or absence of the usual constitutents of the ash, in the hydrochloric acid extract, will give an indication of the quality of black used.

AGRICULTURAL CHEMISTRY.

Sir E. J. RUSSELL, D.Sc., F.R.S., and H. J. PAGE, B.Sc., A.I.C.

Soil Analysis.

Soil analysis only serves to compare one soil with another, and its whole value is determined by the reliability of the standard against which the soil is to be measured and the degree to which comparisons can be instituted between them. After ascertaining the source of the soil, the position and geological formation, the analyst should direct enquiries to the County Agricultural Expert at the under-mentioned places as to the results of field experiments made on similar soils in the same area, and, further, whether the conditions are sufficiently similar to the soil he is studying to justify him in using the results as standards.

Armstrong College, Newcastle-on-Tyne	Cumberland, Durham, Northumberland, Westmorland.
Leeds University	Yorkshire.
Midland Agricultural College, Kingston, Derby	Derby, Leicester, Lincoln (Lindsay), Notts., Rutland.
School of Agriculture, Cambridge	Bedfordshire, Cambridge, Herts., Hunts., Ely, Lincoln (Holland and Kesteven), Norfolk, Suffolk (East and West).
School of Rural Economy, Oxford	Oxford, Northampton.
Wye Agricultural College ..	Kent, Surrey, Sussex.
Reading University College ..	Berks., Bucks., Hants., Dorset, Isle of Wight, Middlesex, Oxford.
Bristol University .. .	Gloucester, Hereford, Somerset, Worcester, Wilts.
Harper Adams College, Newport, Salop	Shropshire, Staffs., Warwick.
Seale-Hayne Agricultural College, Devon	Devon and Cornwall.
Aberystwyth University College	Brecon, Cardigan, Carmarthen, Merioneth, Montgomery, Pembroke, Radnor.
Bangor University College ..	Anglesey, Carnarvon, Denbigh and Flint.

Sampling. Owing to the variation in composition of the soil at different depths it is particularly necessary that the

sample should always be taken to the same depth and with a tool making a clean vertical cut. A suitable tool consists of a steel tube 2 ins. in diam. and 12 ins. long, with a ¾ in. slit cut lengthwise and all its edges sharpened, fixed on to a suitable handle. A mark is made 9 in. from the bottom so that the boring process can be stopped as soon as this depth is reached. After withdrawing the tool, the core of soil is removed by a pointed iron rod. Five or six samples should be taken along lines crossing the field so as to get as representative a sample as possible; the whole bulk must then be sent to the laboratory. Samples should not be taken from freshly ploughed or recently manured land. In very stony soils it is easier to use a 2 in. auger, but this does not yield as satisfactory a sample as the tool described. For precautions to be taken in drawing the sample see Russell (*Journ. Bd. of Agric.*, 1916, **23**, 342), and for a discussion of the magnitude of the experimental error see Robinson (*Journ. Agric. Sci.*, 1915, **7**).

The soil is spread out to dry, and is then pounded with a wooden pestle and passed through a 3 mm. sieve. The stones and fine earth are weighed separately, and the proportion of stones to 100 parts of fine earth is calculated. Subsequent analytical operations are made on the fine earth. For the determination of the "available" constituents, the "fine earth" is used without grinding. For other determinations, 100 grm. or more of "fine earth" is sifted through a 1 mm. sieve. The part retained by the sieve is ground until it will pass through, and the whole mixed.

Moisture. 4–5 grm. of the soil are dried at 100°C. until there is no further change in weight.

Organic matter. No accurate method of estimation has yet been devised. It is usual to ignite at low redness the sample dried as above. The loss includes organic matter, water not given off at 100°C., and carbon dioxide from the carbonates; allowance may be made for the latter, but not for the combined water. Provided soils from the same district and from the same depth are being compared, the clay content, on which the amount of combined water mainly depends, will probably be similar; although the actual values for loss on ignition may be markedly larger than the true content of organic matter, the differences between these values for such soils usually represent fairly closely the differences in content of organic matter. The carbon is sometimes determined either by the ordinary combustion or by some wet combustion method. Methods have also been described for determining "humus," but they have not come into general use. A convenient method

for estimating colorimetrically the content of humic matter in mineral soils has been described by Eden (*Journ. Agric. Sci.*, 1924, **14**, 469).

Total nitrogen. Kjeldahl's method is almost invariably adopted. About 25 to 30 grm. of soil are ground up finely in an iron mortar; 10 to 15 grm. are heated in a Kjeldahl flask with 20 to 25 cc. of concentrated sulphuric acid for ¾ hr.; 5 grm. of potassium sulphate and then a crystal of copper sulphate are added. The heating is continued until the liquid is straw-yellow or colourless. The mixture is diluted when cool, and the liquid decanted, washing the sand by decantation, and the ammonia content estimated.

Nitrates. The fresh soil is rubbed through a 3 mm. sieve, and portions of 250 grm. taken for analysis. If possible, the soil should be extracted at once in the moist condition, but if this cannot be done, the soil should be dried by spreading out in a thin layer in an oven at 50–55°C. for 24 hrs. This drying causes the results to be about 2 parts per million higher than with undried soil; but, provided the conditions of drying are kept uniform, comparable results are obtained. If a vacuum ovum is available, the soil can be dried at 55°C. *in vacuo* in less than 2 hrs. without appreciable change of nitrate content.

The fresh or dry soil is extracted on a Buchner funnel with hot distilled water in small quantities, using just enough suction to secure a steady dropping from the funnel. By the time 400 cc. have been collected the whole of the nitrate is usually extracted. The extract is made up to 500 cc., and duplicate determinations are made on 200 cc. portions. The solution is gently boiled for 6 hrs. with 10 cc. of 8% caustic soda and 10 cc. of 3% potassium permanganate. More of the latter is added from time to time if required, together with more water. The volume of the liquid is then made up to about 300 cc., 20 cc. of 40% caustic soda and 5 cc. of alcohol added, followed by 3 grm. of powdered Devarda alloy. The flask is immediately connected to a block-tin condenser fitted with a special spray trap (filled with glass beads or quartz fragments), and with a short length of hard glass tubing at its lower end, dipping into N/50 sulphuric acid in the receiver. The heating, which must be very gentle until the initial reaction has moderated, is so regulated that 200 cc. of distillate are collected in 50 mins. The back titration is carried out with N/50 caustic soda, using methyl red as indicator; CO_2 is boiled off when the end point is almost reached, and the liquid cooled, before finally determining the end point. Devarda's alloy always contains a little nitrogen, so that it

is necessary to carry out a blank determination with the reagents, and correct the results accordingly.

The older zinc-copper couple method is described by Russell (*Journ. Agric. Sci.*, 1914, **6**, 53). The rapid phenol sulphonic acid method, as used in the United States, is useful when a large number of estimations have to be made and the highest accuracy is not essential.

Ammonia may be estimated by distilling with magnesia and water under reduced pressure (Russell, *Journ. Agric. Sci.*, 1910, **3**, 233), but more accurate results are given by the aeration method of Matthews, which, however, requires special apparatus (*Journ. Agric. Sci.*, 1920, **10**, 72). Results agreeing closely with those given by the latter method are obtained by leaching the soil with sodium chloride solution, followed by distillation of the extract with magnesia (Maclean and Robinson, *Journ. Agric. Sci.*, 1924, **14**, 548). For older methods see Potter and Snyder (*Iowa Research Bull.*, No. 17, 1914).

Carbonates are determined by measurement of the amount of carbon dioxide evolved on treatment of the soil with acid. Collins' calcimeter (*J.S.C.I.*, 1906, **25**, 518) gives results of sufficient accuracy for most purposes. For more accurate methods see Amos (*Journ. Agric. Sci.*, 1905, **1**, 322), Hutchinson (*Journ. Agric. Sci.*, 1914, **6**, 323), Hall and Russell (*Journ. Chem. Soc.*, 1902, **81**, 81).

Lime requirement. Hutchinson and McLennan's method for the determination of the lime requirements of the soil is as follows: 10 to 20 grm. of the soil are placed in a bottle of 500 to 1000 cc. capacity together with 200 to 300 cc. of approximately N/50 solution of calcium bicarbonate, and the air in the bottle is displaced by a current of carbon dioxide in order to avoid possible precipitation of calcium carbonate during the period of the determination. The bottle is then placed in a shaking machine for three hours, after which time the solution is filtered and an aliquot portion of the filtrate is titrated against N/10 acid, using methyl orange as indicator. The difference in strength of this filtrate and that of the initial solution represents the amount of calcium carbonate absorbed, each cubic centimetre of N/10 acid being equal to 5 mgrm. calcium carbonate. For a critical investigation into the reaction between soils and calcium bi-carbonate, with special reference to the above method, see Crowther and Martin (*Journ. Agric. Sci.*, 1925, **15**, 237.)

There are numerous other methods in existence; for an account of these see Christensen (*Soil Sci.*, 1917, **4**, 115).

Soil reaction. The indicator method of determining pH has been applied to soils (see Fisher, *Journ. Agric. Sci.*, 1921, **11**, 10 and 45), but has been found not to be of universal applicability, owing to the disturbing effect of the clay fraction. The electrometric method gives reliable and accurate results, but special precautions and complicated apparatus are needed. (See Crowther, *Journ. Agric. Sci.*, 1925, **15**, 201.) The use of the quinhydrone electrode for determination of soil reaction has been described by Bülmann (*Journ. Agric. Sci.*, 1924, **14**, 232). A simple and useful test for acid soils is that devised by Comber (*Journ. Agric. Sci.*, 1920, **10**, 420). 2 or 3 grm. of air-dried soil are shaken vigorously in a test-tube with 5 cc. of a saturated alcoholic solution of potassium thiocyanate. A pink or red colour develops at once, or on standing, if the soil is acid. The liquid may be filtered if the colour is faint. This test is not quantitative, but applied to different samples of the same soil, the degree of acidity, if any, is roughly indicated by the intensity of the red colour. A simplified form of this test, involving the use of aqueous potassium salicylate instead of alcoholic potassium thiocyanate, can be applied directly to the moist soil. (Comber, *Journ. Agric. Sci.*, 1922, **12**, 370). Other useful tests for detecting soil acidity and for roughly gauging the "lime requirement," are those of Truog (*Wisconsin Agr. Exp. Sta. Bull.*, 321, 1921) and of Spurway (" Soiltex " method, *Michigan Quart. Bull.*, 1924, **16**, 93, and *U.S. Pat.* 1,520,891).

Mineral substances. Complete analysis of a soil after the silicates have been decomposed and the silica volatilised by treatment by hydrofluoric acid is only rarely attempted. The British method, adopted by the Agricultural Education Association, is described as follows by Hall (*The Soil*): 20 grm. of the powdered soil are placed in a resistance-glass flask, covered with about 70 cc. of concentrated hydrochloric acid, and boiled for a short time. The flask is loosely stoppered, and the contents allowed to digest in the water-bath for about 48 hrs. The solution is then cooled, diluted, and filtered. The washed residue is dried and weighed as material insoluble in acid. The solution is made up to 250 cc., and aliquot portions taken for the various determinations. The analytical operations are carried out in the usual manner, but special care must be taken to free the solution from silica or organic matter. Hissink has discussed the value of concentrated hydrochloric acid as a solvent in soil analysis (*Internat. Mitt. Bodenkunde*, 1915, **5**, 1).

As a rule only potash and phosphoric acid are determined, but where other bases are required, they are estimated in

the usual way. For determination of iron see Morison and Doyne (*Journ. Agric. Sci.*, 1914, **6**, 97.)

Potash.—50 to 100 cc. of the solution are evaporated to dryness, after addition of 0.5 grm. of pure $CaCO_3$ (in many cases 0.1 grm. is sufficient) if the original soil did not effervesce on addition of hydrochloric acid, and treated by one of the following methods:

(a) The residue is gently ignited over a Bunsen flame until completely charred, and is then extracted with water until all the potassium chloride has dissolved (Neubauer's method, *Landw. Versuchs. Stat.*, 1905, **63**, 141). The older method due to Tatlock is still sometimes used; it is described by Dyer (*Journ. Chem. Soc.*, 1894, **65**, 115). To the clear filtrate 5 cc. of platinic chloride (containing 0·005 grm. Pt per cc.) are added, and the mixture slowly concentrated on the water-bath to a very small bulk; the potassium platinichloride is filtered off in a Gooch crucible, washed with 80% alcohol, dried and weighed.

(b) 10 cc. of 5% baryta solution are added, the liquid evaporated to dryness, ignited, the residue taken up with water as in (a); 2·5 cc. perchloric acid (Sp. Gr. 1·12) are added, the mixture concentrated until dense fumes are given off; the precipitate is redissolved in hot water, a little more perchloric acid added, and the whole concentrated again to the fuming stage, allowed to cool, and 20 cc. 95% alcohol added with stirring. After decanting the clear alcohol, 20 cc. alcohol, containing 0·2% perchloric acid, are added, and the insoluble potassium perchlorate transferred as completely as possible by means of it to a tared filter paper, or to a weighed Gooch crucible or Soxhlet tube well packed with asbestos. The acid alcohol is allowed to drain away as completely as possible, and the whole of the precipitate collected in the paper, crucible or tube, and washed till no longer acid, with 95% alcohol saturated at the laboratory temperature with potassium perchlorate. The precipitate is dried at 100°C., and weighed as $KClO_4$. Care must be taken that the perchloric acid is pure. Chloric acid is sometimes present in impure samples, and, besides leading to deflagrations on the addition of alcohol, gives rise to high results. (Page. *Journ. Agric. Sci.*, 1924, **14**, 133.) Christensen and Feilberg (*Landw. Vers.-St.*, 1921, **97**, 27) have modified the cobaltinitrite method due to Mitscherlich, and claim that in its improved form it yields accurate results.

Phosphoric acid. The charred residue from which the potassium chloride has been removed is digested for ½ hr. with

50 cc. of 10% sulphuric acid and filtered; the filtrate is treated with 25 cc. of concentrated ammonium nitrate solution, and warmed to 55°C.; 25 cc. ammonium molybdate, previously warmed to 55°C., is added, and the liquid allowed to stand for 2 hrs. and filtered. After washing with 2% sodium nitrate until neutral, the precipitate and filter paper are transferred to the beaker used for the precipitation, and a known volume of standard alkali added so that the precipitate dissolves completely. The excess alkali is determined by titration, using phenolphthalein as indicator.

$$1 \text{ cc. of } N/10 \text{ alkali} = 0.0003004 \text{ grm. } P_2O_5.$$

Originally described in *Bull.* 46 (revised) *United States Division of Chemistry* (Washington, 1898), this volumetric method has been carefully examined by Prescott (*Journ. Agric. Sci.*, 1914, **6**, 111), and the above conditions laid down under which it gives satisfactory results. Instead of the above volumetric method, the yellow precipitate of ammonium phosphomolybdate, obtained as above, can be filtered on a Gooch crucible, and either weighed as $(NH_4)_3PO_4.12MoO_3$ (factor for $P_2O_5 = 0.03753$) after drying at 160–180°C., or, more conveniently, ignited gently (inside a nickel crucible lined at the bottom with asbestos paper), to the bluish-black phosphomolybdic anhydride, $24MoO_3,P_2O_5$ (containing 3.946% P_2O_5), and weighed in this form. The older method is described by Dyer (*Journ. Chem. Soc.*, 1894, **65**, 116).

"Available" potash and phosphoric acid. Dyer's directions are as follows: 200 grm. dry soil are placed in a $2\frac{1}{2}$ litre bottle with 2 litres of distilled water in which are 20 grm. of pure citric acid. The soil is allowed to remain in contact with the solution at ordinary temperatures for 7 days, shaking several times each day. Substantially similar results are obtained by shaking for 24 hrs. in a mechanical shaker (Hall and Amos, *Journ. Chem. Soc.*, 1906, **89**, 205). The solution is then filtered, and 500 cc. taken for each determination; this is evaporated to dryness, and gently incinerated at a low temperature. The residue is moistened with concentrated hydrochloric acid, the liquid evaporated to dryness, the residue gently ignited, and then extracted with hot water and filtered; the potash is determined in the filtrate. For the phosphoric acid determination the final solution of the residue is carried out, as before, with 10% sulphuric acid.

For a discussion of the estimation of "available" potash and

phosphoric acid in soils, in which reference is made to other methods in use in the United States and on the Continent, see Page, "Annual Reports on Applied Chemistry" (*Soc. Chem. Ind.*) 1923, **8**, 427.

Exchangeable bases. The determination of the amount of bases, especially of lime, that can be liberated from the soil by base exchange with a neutral salt, is becoming of increasing importance in soil investigations. The most convenient and reliable method is that of Hissink (*Internat. Mitt. Bodenkunde*, 1922, **12**, 81), which is as follows : 25 grm. of air-dried soil are treated with 100 cc. of a normal salt solution and the whole is heated on a sand-bath to about 80°C. for an hour, with occasional stirring. After cooling and allowing to stand over-night, the supernatant liquid is decanted through a filter-paper ; the soil is transferred to the filter by a jet of the salt solution. The soil is then leached on the funnel with the same strength of salt solution until the required volume is obtained, the filtrate being collected in a graduated flask. Leaching to 500 cc. with *N*. ammonium chloride is used for all determinations except that of exchangeable calcium in soils containing calcium carbonate ; in the latter case ammonium chloride is not suitable owing to its solvent power on calcium carbonate ; ; normal sodium chloride is used and leaching is continued until two successive litres of extract are obtained. The difference between the calcium content of the first and second litres represents the amount of exchangeable calcium.
After concentration of the extract to suitable volume, calcium, magnesium, potassium and sodium (and if necessary iron, aluminium and silica) are determined by the usual methods. The use of the volumetric method of calcium determination (titration with permanganate after solution of the precipitated calcium oxalate in sulphuric acid), besides being more accurate where the amount of calcium is small, obviates the necessity of removing the hydroxides of iron and aluminium, and silica, from the calcium oxalate precipitate. In removing calcium as oxalate from an extract in which magnesium is to be determined, it is usually necessary to carry out a double precipitation, to avoid loss of magnesium in the calcium oxalate precipitate ; in the case of acid soils, some silica is likely to remain in solution after removal of calcium. This must, of course, be removed before precipitation of the magnesium. Sodium is determined by weighing the mixed chlorides or sulphates of magnesium, potassium and sodium and subtracting the values found separately for the first two. It is usually most convenient and rapid to determine calcium,

magnesium and potassium on separate extracts rather than to attempt to make all the determinations on one extract.

Mechanical analysis. The object is to obtain information about the size of the ultimate particles of which the soil is composed; the compound particles are therefore broken down by treatment with hydrochloric acid, and afterwards with ammonia. Direct measurement of the ultimate particles is found to be impracticable; indirect methods have to be adopted, depending on the time taken to fall through a column of water of given height. If v = velocity of the falling particle, a its radius (assuming it to be a sphere), it has been calculated that $a = \sqrt{v}/171$ cm.

The method adopted by the Agricultural Education Association (*Journ. Agric. Sci.*, 1906, **1**, 470) is as follows:

(1) 10 grm. of the air-dried earth, which has passed a 3 mm. sieve, are weighed into a porcelain basin and triturated with 100 cc. of N/5 hydrochloric acid, further acid being added if much calcium carbonate is present. After standing in contact with the acid for 1 hr., the mixture is transferred to a dried, tared filter, which is washed until acid-free, dried and weighed. The loss represents hygroscopic moisture and material dissolved by the acid.

(2) The soil is washed off the filter with ammoniacal water on to a small sieve of 100 meshes to the linear inch, the portion passing through being collected in a beaker marked at 10, 8·5 and 7·5 cm. respectively from the bottom. The portion which remains upon the sieve is dried, weighed, and divided into "fine gravel" and "coarse sand" by means of a sieve with round holes of 1 mm. diam. The portion which does not pass this sieve is the "fine gravel." This should be dried and weighed. The difference gives the "coarse sand." If required, both these fractions may also be weighed after ignition.

(3) The portion which passed the 100 mesh sieve is triturated with a rubber pestle (made by inserting a glass rod as handle into an inverted rubber stopper), and the beaker filled up to the 8·5 cm. mark and allowed to stand for 24 hrs. The ammoniacal liquid which contains the "clay" is then decanted into a Winchester quart, repeating the operation as long as any matter remains in suspension for 24 hrs. The liquid containing the "clay" is either evaporated in bulk or measured, and, after being well shaken, an aliquot portion taken and evaporated. In either case the dried residue consists of "clay" and "soluble humus." After ignition the residue gives the "clay," and the loss on ignition the "soluble humus."

The minimum value of $r = 0.0001$ cm. per sec., and the maximum diameter of the particles left in the suspension $= 0.00116$ mm.

(4) The sediment from which the "clay" has been removed is triturated, as before, in the beaker, which is filled to the 10 cm. mark and allowed to stand for 100 secs. The operation is repeated until the "fine sand" settled in 100 secs. is clean, when it is collected, dried and weighed.

The minimum value of $v = 0.1$ cm. per sec., and the calculated minimum diameter of the fine sand $= 0.037$ mm.

(5) The turbid liquid decanted from the "fine sand" is collected in a Winchester quart, or other suitable vessel, allowed to settle, and the clear liquid syphoned or decanted off. The sediment is then washed into the marked beaker and made up to the 7·5 cm. mark. After stirring, it is allowed to settle for $12\frac{1}{2}$ mins., and the liquid decanted off. The operation is then repeated as before until all the sediment sinks in $12\frac{1}{2}$ mins., leaving the liquid quite clear. The sediment obtained is the "silt," which is dried and weighed as usual. The liquid contains the "fine silt," which, when it has settled down, can be separated by decanting off the clear liquid, and dried and weighed.

For silt the minimum value of $v = 0.01$ cm. per sec. and the minimum diameter of particles $= 0.012$ mm. For fine silt the diameter lies between this value, and the one found for clay.

When it is desired to compare the results with American data the fine silt can be divided into two groups : settling for 2 hrs. 5 mins. brings out a group 0·01 to 0·005 mm. diam., and the remainder lies between 0·005 and 0·002 mm. diam. By calculation the fractions can then be made to correspond fairly closely with those adopted in the United States.

(6) Determinations are made of the "moisture" and "loss on ignition" of a further 10 grm. of the air-dried earth. The sum of the weights of the fractions after ignition + loss on ignition + moisture + material dissolved in weak acid should approximate to 10 grm.

(7) It is advisable to make a control determination of the "fine gravel" in a portion of 50 grm. of the air-dried earth. The soil should be treated with acid, as in (1), and after that is removed by decantation may be at once treated with dilute ammonia and washed on the sieve with 1 mm. round holes. The "fine gravel" left on the sieve is then dried and weighed.

The question of the mechanical analysis of soils has recently been carefully considered by a sub-committee of the Agricultural Education Association. This sub-committee carried out

a critical comparison of the above official sedimentation method with the method recently proposed by Robinson (*Journ. Agric. Sci.*, 1922, **12**, 287 and 306). As a result of this comparison, the Agricultural Education Association has now adopted Robinson's method as official, in place of the above method. Full working details of the new official method will be published in "Agricultural progress" at the end of 1925. The main features of the new method are : (1) an improved method of pre-treatment of the soil, in which the humic matter is removed by oxidation with hydrogen peroxide, so that suspension is obtained in which complete dispersion of compound particles is effected ; (2) the finer fractions (clay, fine silt and silt) are determined by withdrawing samples of the suspension by means of a pipette from known depths after known times of sedimentation. The new method is much more rapid than the former method, and is more reliable.

Joseph and Martin (*Journ. Agric. Sci.*, 1922, **11, 293**) describe a sedimentation method similar to the older British one, by using sodium carbonate instead of ammonia for deflocculating the clay, and using the centrifuge to hasten the rate of settling. Good results were obtained with heavy Sudan soils.

An entirely new method has been described by Odén (*Internat. Mitt. Bodenkunde.*, 1915, **5**, 251–346). Expensive and complicated apparatus is, however, needed for this method, which is thus only suitable for research purposes. (See Coutts, Crowther, Keen and Odén, *Proc. Roy. Soc.*, **A.106**, 33.)

Interpretation of Results.

This is by no means an easy problem ; it is discussed at length by Hall (*The Soil*), and by Russell (*Soil Conditions and Plant Growth*).

Some typical results are given in the table on the page following.

Bacteriological Examination of Soils.

The method of counting the number of bacteria present in soils, which has been worked out at Rothamsted, is as follows :—

The freshly sampled soil is passed through a 3 mm. sieve and thoroughly mixed (aseptic technique is not needed at this point, unless qualitative examination for species is also

contemplated). 10 grm. are weighed out, transferred to 250 cc. of sterile saline (5 grm. NaCl, 1 grm. $MgSO_4.7H_2O$, 1 litre H_2O), and the flask shaken for 4 mins., the cotton wool plug being replaced by a sterile cork. 1 cc. of the resulting suspension is transferred by means of a sterile pipette into 99 cc. of sterile saline and shaken for 1 min. 1 cc. of this suspension is similarly transferred to a second 99 cc. of sterile saline and shaken for 1 min. (In making these transfers it is best to wash out the pipette once with the liquid to which the suspension has just been added, so as to minimise loss of organisms due to adherence to the pipette walls.) Five sterile petri dishes are taken, and to each is transferrd with a sterile pipette 1 cc. of the final suspension (equals 1/250 000 grm. of soil) Before each transfer the flask should be shaken to ensure an even suspension. Into each dish is then poured about 10 cc. of sterile count medium (see below) previously melted and cooled to 42°C., and the dish at once carefully oscillated so as to mix the medium well with the soil suspension and give a uniform mixture before the medium sets. The plates are allowed to stand till the medium is quite firm, then they are incubated in an inverted position at 20°C. for 10 days. The number of colonies on each plate is counted (some practice is needed to distinguish bacterial colonies from those of moulds and acetomycetes) and the mean value for the five plates, divided by four, gives the number of bacteria in the fresh soil in millions per gramme (m.p.g.). The result is a minimum one, since the whole of the bacteria in the soil are incapable of developing on any one medium, but the value obtained should be quite suitable for comparative purposes.

Agar count medium (Thornton, *Ann. Appl. Biol.*, 1922, **9**, 241). K_2HPO_4 1 grm., $MgSO_4.7H_2O$ 0·2 grm., $CaCl_2$ 0·1 grm., NaCl 0·1 grm., KNO_3 0·5 grm., $FeCl_3$ 0·002 grm., asparagine 0·5 grm., mannitol 1 grm., agar 15 grm., water to 1000 cc. The phosphate, nitrate and asparagine are first added, followed by the other salts, previously dissolved in water, and finally the agar. The whole is heated in the steamer until the agar is dissolved, and then filtered in the steamer at 100°C., bing passed twice through a $\frac{1}{2}$ in. layer of absorbent cotton wool. The mannitol is added to the filtrate, and the reaction of the medium adjusted to pH 7·4 with caustic soda (see Gillespie, *Soil Sci.*, 1920 **9**, 115, for simple method of adjusting pH). It is filled into tubes in 10 cc. lots and sterilized in the autoclave at 15 lb. for 15 mins.

Mechanical and Chemical Analysis of Typical Soils.

Formation.	Folkestone Beds.		Thanet Beds.		Brick	Earth	London Clay	Weald Clay	Alluvium	
Character of Soil.	Waste.	Poor light arable.	Good but light.	Very good arable.	Very good arable.	Very good arable.	Heavy, grass best.	Heavy poor grass.	Good grass or arable.	Heavy grass land.
SOIL										
Gravel	1.2	2.5	0.2	0.2	0.3	0.9	0.4		0.7	0.1
Coarse Sand	65.9	52.6	15.3	2.3	0.7	1.3	12.8	1.5	1.0	0.5
Fine Sand	23.7	23.2	44.9	34.7	24.7	16.0	25.5	11.0	19.8	19.3
Silt	2.4	4.8	17.3	36.2	44.8	35.5	11.3	19.6	28.4	13.0
Fine Silt	2.0	3.5	6.3	6.3	8.6	13.3	11.1	26.8	12.1	20.0
Clay	0.9	3.8	8.9	11.5	14.7	15.9	23.7	22.1	19.7	26.9
Moisture	0.48	1.11	2.21	2.27	2.45	3.32	4.92	4.87	4.76	4.00
Loss on ignition	2.62	3.27	3.17	4.32	4.65	6.58	5.61	9.80	10.21	11.33
Nitrogen	0.033	0.137	0.119	0.140	0.120	0.220	0.241	0.310	0.339	0.554
Al_2O_3	nil	1.55	2.07	3.46	3.33	5.50	5.95		6.45	
Fe_2O_3	2.24	5.24	2.44	2.56	2.50	3.05	3.80		4.26	
Mn_3O_4	trace	0.03	trace	0.02	0.05	0.06	0.03		nil	
MgO	0.06	0.18	0.32	0.46	0.52	0.40	0.97	0.16	0.30	0.28
*Carbonates	nil	0.35	0.08	0.18	0.40	0.75	2.00		0.05	
CaO	0.05	0.41	0.51	0.67	0.82	1.79	1.51	0.46	0.81	0.22
K_2O	0.025	0.158	0.392	0.404	0.31	0.43	0.54		0.51	
†"Available" K_2O	0.010	0.007	0.012	0.015	0.010	0.014	0.016	0.006	0.031	0.014
P_2O_5	0.081	0.191	0.064	0.119	0.074	0.138	0.118	0.104	0.343	0.102
†"Available" P_2O_5	0.004	0.047	0.013	0.048	0.008	0.020	0.019	0.003	0.064	0.006
SO_3		0.034	0.04	0.05	0.03	0.06	0.05		0.08	
SUBSOIL										
Moisture	0.48	1.06		2.67	3.15	3.21	6.88	3.46	4.55	3.84
Loss on ignition	2.03	2.25		3.09	3.00	4.94	5.07	2.59	7.33	8.84
Nitrogen	0.026	0.059		0.088	0.078	0.139	0.097	0.129	0.173	0.202
*Carbonates	0.02	0.12		0.03	0.08	0.66	0.52	54.8	nil	0.19
K_2O	0.014	0.144		0.441	0.46	0.47	0.572	0.229	0.75	0.34
P_2O_5	0.044	0.174		0.053	0.067	0.101	0.042	0.036	0.245	0.079

*Calculated as $CaCO_3$. †Soluble in 1% Citric Acid.

Analysis of Manures.

Unlike the analysis of soils, the analysis of manures is not a comparative process, but aims at obtaining absolute results. In the case of phosphate fertilisers it is necessary to give some indication as to solubility, and in that case carefully prescribed methods must be followed. Official methods (*Board of Agriculture Leaflet*, No. 18) have been prescribed for sampling and for all determinations, and these must be rigidly followed wherever a dispute is likely to be involved.

The sample must be prepared for analysis in the following manner : Powdered fertilisers in a dry, or moderately dry, condition must first be passed through a 1 mm. mesh sieve, powdering if necessary ; adventitious materials which cannot be conveniently crushed, *e.g.*, fragments of metal in basic slag, are removed and allowed for. Wool, hair, hoof, shoddy, and similar substances, are pulled apart and cut until in a fine condition, or, if dry, may be passed through a shredding machine. In the case of horn, shoddy, and other substances which gain or lose water during the process of pulverising, the proportion of water is estimated in the coarse and in the powdered condition respectively, and the results of the analysis of the powdered sample are calculated to the original substance.

The official method of analysis is as follows :

Determination of moisture. A weighed quantity of the sample is dried at 100°C.

Determination of nitrogen. The presence or absence of nitrates must first be ascertained.

(*a*) In absence of nitrates a weighed portion of the sample is transferred to a Kjeldahl flask, 10 grm. of potassium sulphate and 25 cc. of concentrated sulphuric acid added, and the flask heated until a clear liquid, colourless, or of light straw colour, is obtained. The operation may be accelerated by the addition of a small crystal of copper sulphate or a globule of mercury to the liquid in the digestion flask. The quantity of ammonia is determined by distillation into standard acid after liberation with alkali, and, where mercury has been used, with the addition also of sodium or potassium sulphide solution.

(*b*) In presence of nitrates, a weighed portion of the sample is transferred to a Kjeldahl flask, 30 cc. of concentrated sulphuric acid containing 1 grm. of salicylic acid added, and the flask shaken immediately and at intervals during 10 mins., being kept cool meanwhile. 5 grm. of sodium thiosulphate and 10 grm. of potassium sulphate are added, and the flask heated until the contents are colorless or nearly so. Copper sulphate

or mercury may be used as described above. The quantity of ammonia is determined as above.

(c) Nitrogen in form of ammonium salts is determined after addition of alkali in the usual manner.

(d) Nitrogen in nitrates in the absence of ammonium salts and of organic nitrogen : 1 grm. of the sample is placed in a ½ litre Erlenmeyer flask with 50 cc. of water, 10 grm. of reduced iron and 20 cc. of sulphuric acid (Sp. Gr. 1·35) added, and the flask closed with a rubber stopper provided with a thistle tube, the head of which is half-filled with glass beads. The liquid is boiled for 5 mins., and the beads are rinsed with water into the flask. The solution should be boiled for 3 mins. more. After boiling for a further 3 mins. the beads are again washed with water. The quantity of ammonia is then determined as above. In case the proportion of nitrates is small, a larger quantity of the sample is taken.

(e) A control experiment is carried out under similar conditions with the same quantities of the reagents which have been employed in the actual analysis, 1 grm. of pure sugar being used in (a) in place of the sample ; a suitable correction is then made.

Determination of phosphates.

(a) Phosphates soluble in water. In the case of superphosphates, dissolved bones and simlar substances, 20 grm. of the sample are shaken continuously for 30 mins. in a litre flask with 800 cc. of water. The flask is then filled to the mark, again shaken, and the contents filtered. 50 cc. of the filtrate are boiled with 20 cc. of concentrated nitric acid, and the phosphoric acid determined by the molybdate method described below. In the case of fertilisers in which the proportion of phosphates soluble in water is small, a larger quantity of the filtrate prepared as above is taken.

(b) Phosphates soluble in citric acid. 5 grm. of the sample are treated with 10 grm. of pure crystallised citric acid, made up to 500 cc. with water. To avoid caking, the sample may be moistened with 5 cc. of methylated spirit before the citric acid solution is added, in which case the volume of the citric acid solution should be 495 cc. instead of 500 cc. The bottle is at once fitted into a mechanical shaking apparatus and continuously agitated for 30 mins. The solution is then filtered through a large fluted filter, the whole of the liquid being poured on the paper at once ; if not clear, the filtrate is again poured through the same paper. The phosphoric acid is determined in 50 cc. of the filtrate by the molybdate method described below.

(c) Total phosphoric acid. A weighed portion of the sample, in which, if necessary, the organic matter has been destroyed by ignition and the silica removed, is dissolved in nitric acid, the solution boiled, and the phosphoric acid determined by the molybdate method.

(d) Molybdate method. Molybdic acid solution : 125 grm. of molybdic acid and 100 cc. of water are placed in a litre flask, and the molybdic acid dissolved by shaking with 300 cc. of 8% ammonia (Sp. Gr. 0·967) ; 400 grm. of ammonium nitrate are added, the solution made up to the mark with water, and added to 1 litre of nitric acid (Sp. Gr. 1·19). After keeping at about 35°C. for 24 hrs., the solution is filtered.

Magnesia mixture : 110 grm. of crystallised magnesium chloride and 140 grm. of ammonium chloride, dissolved in 1,300 cc. of water, are mixed with 700 cc. of 8% ammonia, allowed to stand for not less than 3 days, and then filtered.

An amount of the solution, containing from 0·1–0·2 grm. of P_2O_5, is treated with 100 to 150 cc. or an excess of molybdic acid solution, and the mixture placed in a water-bath at 70°C., for 15 mins. After allowing to cool, the solution is filtered, and the phospho-molybdate precipitate washed several times by decantation and finally on to the filter with 1% nitric acid. The filtrate and washings are mixed with further molybdic acid solution and allowed to stand for some time in a warm place in order to ascertain whether the P_2O_5 has been completely precipitated. The phospho-molybdate precipitate is dissolved in cold 2% ammonia, using about 100 cc. of ammonia for the solution and washings. 15–20 cc. or an excess of magnesia mixture is then added drop by drop with constant stirring. After allowing to stand for at least 2 hrs. with occasional stirring, the precipitate is filtered off, washed with 2% ammonia, dried and finally weighed as magnesium pyrophosphate. The filtrate and washings are tested by the addition of further magnesia mixture.

Determination of potash.

(a) Muriate of potash free from sulphates. A weighed portion of the sample (about 5 grm. in the case of concentrated muriate of potash or 10 grm. in the case of low-grade muriate) is dissolved in water, the solution filtered if necessary, and made up to 500 cc. To 50 cc. of the solution in a porcelain basin, several drops of HCl are added, and then 10 cc. or 20 cc. (according to whether the portion weighed was 5 grm. or 10 grm.) of a solution of platinum chloride containing 10 grm. Pt per 100 cc. After evaporation to a syrupy consistency on a water-bath, the contents of the basin are allowed to cool,

and then treated with alcohol (Sp. Gr. 0·864), being washed by decantation until the alcohol is colorless. The washings are filtered through a weighed or counterpoised filter paper, on which the precipitate is finally collected, washed with alcohol as above, dried at 100°C., and weighed as $K_2 Pt Cl_6$.

(b) Potassium salts containing sulphates. A weighed portion of the sample (about 5 grm. in the case of concentrated sulphate of potash or 10 grm. in the case of kainit or other low-grade salts) are boiled with 20 cc. of hydrochloric acid and 300 cc. of water in a $\frac{1}{2}$ litre flask. Barium chloride solution is added drop by drop to the boiling solution until the sulphuric acid is completely precipitated; any slight excess of barium is removed by the addition of the least possible excess of dilute sulphuric acid. (It is often more convenient to estimate the sulphuric acid and add the exact amount of barium chloride.) The liquid, without filtration, is cooled and made up to 500 cc. A portion is then filtered, and 50 cc. of the filtrate treated as in (a).

(c) Potash in guanos and mixed fertilisers. 10 grm. of the sample are gently ignited to char organic matter present, heated for 10 mins. with 10 cc. of concentrated hydrochloric acid, and finally boiled with 300 cc. of water. The liquid is filtered into a $\frac{1}{2}$ litre flask, raised to the boiling point, and a slight excess of powdered barium hydroxide added. The contents of the flask are cooled, made up to 500 cc., and filtered. 250 cc. of the filtrate are treated with ammonia solution and excess of ammonium carbonate, and then, whilst boiling, with a small amount of powdered ammonium oxalate, cooled, made up to 500 cc. and filtered. 100 cc. of the filtrate are evaporated in a platinum dish, and the residue heated, first in the air-bath and then very gently over a low flame, until all ammonium salts are expelled, the temperature being carefully kept below that of low redness. The residue is treated with hot water, filtered if necessary, and the potash determined in the filtrate as in (a).

In case no prosecution is likely to be involved, the analyst may use the perchlorate method for determining potash given under "Soil analysis," using, however, sufficient perchloric acid to precipitate the larger amounts of potash in the solution obtained as above.

An account of the preparation and properties of the various fertilisers is given by Hall (*Fertilisers and Manures*), and by Russell (*Soils and Manures*).

The adjoining table gives the composition of typical fertilisers.

TYPICAL ANALYSES OF FERTILISERS.

Fertiliser.	Nitrogen.	Equivt. NH_3.	P_2O_5.	Equivt. to $Ca_3(PO_4)_2$.	K_2O.	Moisture.	Organic Matter.	Sand.
Nitrate of Soda ..	15.5							
Nitrate of Potash ..	14.0							
Nitrate of Lime ..	13.0							
Sulphate of Amm.	20.0							
Nitrolim	15.5	18.8						
Bones (Raw)	5.0	6	22	48				
Bone Meal	3.5—5.0	5—6	20—25	43—55				
Steamed Bone Flour	1—2	1—2.5	25—32	55—69				
Dissolved Bones ..	2—3	2.3—3.8	15—16	33—35				
Superphosphate ..			11.8	26				
,,			13.6	30				
,,			16.0	35				
Basic Slag—								
Bessemer			20	44[1]				
Open Hearth ..			9—15	20—33[2]				
Sulphate of Potash					48.5			
Muriate of Potash					45			
Kainit					12			
Wood Ashes					10			
Farmyard Manure—								
Bullock	0.62		0.26		0.72			
Cow	0.43		0.19		0.44			
Horse	0.54		0.23		0.54			
Liquid	0.20		0.03		0.46			

[1] 80—90 % soluble in 2% citric acid.   [2] 20—80% soluble in 2% citric acid.

TYPICAL ANALYSES OF FERTILISERS. —*Continued.*

Fertiliser.	Nitrogen.	Equivt. NH₃.	P₂O₅.	Equivt. Ca₃(PO₄)₂.	K₂O.	Moisture.	Organic Matter.	Sand.
Peruvian Guano—								
High Grade ..	10—14		9—11	20—24	2—4	60—70		7—12
Ordinary ,, ..	5—8		14—18	30—40	2—4	40—50		9—25
Phosphatic ,,	2.5—3.5		18—32	40—70	2—6	22—25		4—6
Ichaboe Guano ..	8		9—14	20—30	2	50—60		15—25
Fish Guano	8—10		4.5—9	10—20				
Pure Flesh (fat-free	16.7							
Meat Guano—								
High Grade ..	8—9		4.6—7	10—14				
Phosphatic ...	4—5		16—18	35—40				
Blood (dried)	12							
Hoofs and Horns..	12—14							
,, mixed with Bone	10			20—25				
Rape Cake	5		2	4	1			
Seaweed (wet)	0.5		0.09		1.5	75		
Shoddy—								
High Grade ..	12—14							
Medium ,, ..	5—8							
Low ,, ..	3							
Hair, Calf hair, &c.	10							
Feathers	9							
Rabbit Waste	7							
Leather Waste	3.3							
Soot		4					18	
Sewage Sludge .... + lime	1		1			50	15—25	25—35

Analysis of Feeding Stuffs.

This is distinctly more conventional than the analysis of fertilisers or even of soils, and is therefore more definitely limited in its scope, the main object of the analysis being to compare one feeding stuff with another of the same kind. Analysis rarely affords a sufficient basis on which to pronounce an opinion on an unknown material, as it can never show whether the material will prove palatable or even poisonous to the animal. Feeding trials must always be made with new substances.

The method of sampling and of analysis of feeding stuffs are prescribed in the *Board of Agriculture Leaflet*, No. 18.

The sample is prepared for analysis in the following manner : If the sample is not in a fine condition, it is carefully pulverised until it passes through a 2–3 mm. sieve, thoroughly mixed, and a portion immediately taken for the determination of moisture by drying at 100°C. A portion of not less than 100 grm. is further powdered if necessary to pass through a 1 mm. sieve and preserved in a stoppered bottle.

In case the original sample is appreciably damp, or if pulverisation and mixing are likely to result in loss or gain of moisture, the moisture is redetermined in this portion, and the results of analysis suitably corrected.

Determination of oil.

A quantity of the sample is weighed into a thimble, and extracted with washed redistilled ether in a Soxhlet apparatus. After 3–4 hrs. the thimble is removed, dried, and its contents finely ground in a small mortar previously rinsed with ether; the substance is then returned to the thimble, the mortar being washed out with ether, and the extraction continued for another hour. After evaporation of the ether the oil is dried at 100°C. and weighed. The oil is then redissolved in ether and any insoluble matter weighed and deducted.

In the case of samples containing saccharine matter, *e.g.*, sugar meals, the weighed portion in the Soxhlet thimble is washed twice with water and then dried, previous to the extraction.

Determination of fibre.

The residue in the thimble is transferred to a beaker, 50 cc. of 5% H_2SO_4 and 75 cc. water are added, and the liquid boiled gently for $\frac{1}{2}$ hr., stirring to avoid frothing, hot water being added as required to keep the volume constant. Cold water is added, and the mixture allowed to stand for 1 hr. The liquid is then filtered through linen, and the

residue washed back into the beaker with a small amount of hot water. 50 cc. of 5% KOH are added, and the liquid made up with water to the original volume, boiled for $\frac{1}{2}$ hr.; cold water is then added, and the liquid allowed to stand and again filtered through linen, washing with hot water, then dilute hydrochloric acid, and finally with alcohol. The residue is transferred to a crucible, dried, and weighed; it is then ignited to obtain weight of mineral matter, which must be deducted from the weight of fibre.

Carbohydrates are estimated by difference; the content of oil, fibre, albuminoids, moisture and total ash is subtracted from 100 per cent.

Determination of albuminoids.

The total nitrogen is determined by the Kjeldahl method as under "Manures."

$$\% \text{ albuminoids} = 6.25 \times \% \text{ N}.$$

The properties of feeding stuffs are described by Henry and Morrison (*Feeds and Feeding*), Kellner (translated by Goodwin, *Scientific Feeding of Farm Animals*), and Armsby (*Principles of Animal Nutrition*).

A complete list of the composition of typical feeding stuffs has been published by Wood (*Composition and Nutritive Value of Feeding Stuffs*).

Average Percentage Composition of Typical Feeding Stuffs.

(Wood, "Composition and Nutritive Value of Feeding Stuffs.")

Roots.	Water.	Protein.	Oil.	Carbohy-drate.	Fibre.	Ash.
Mangolds (yellow fleshed, globe or tankard)	86.8	1.2	0.1	9.9	0.8	0.9
Potatoes	76.2	2.1	0.1	19.7	0.9	1.0
Sugar Beet	76.6	1.1	0.1	20.4	1.1	0.7
Turnip	91.5	1.0	0.2	5.7	0.9	0.7
Grasses.						
Pasture Grass, average........	80.0	3.5	0.8	9.7	4.0	2.0
,, rich	78.2	4.5	1.0	10.1	4.0	2.2
Hay.						
Meadow Hay, poor	14.3	7.5	1.5	38.2	33.5	5.0
,, good	14.3	9.7	2.5	41.4	26.3	6.2
,, very good	16.0	13.5	3.0	40.4	19.3	7.7
Straws.						
Barley Straw, Spring	14.0	3.3	1.8	42.4	33.9	4.6
Bean Straw (incl. pods)	14.0	4.5	0.8	33.0	43.5	4.6
Oat Straw, Spring	14.0	2.9	1.9	42.4	33.9	4.9
,, Winter.	14.0	1.9	1.6	43.1	34.6	4.9
Wheat Straw, Spring	14.0	2.9	1.3	39.8	35.9	5.1
,, Winter	14.0	2.1	1.3	40.7	36.6	5.3

	Water.	Protein.	Oil.	Carbohydrate.	Fibre.	Ash.
Cereals.						
Barley, Feeding	14.3	12.0	2.4	63.7	5.0	2.0
Maize	13.0	9.9	4.4	69.2	2.2	1.3
Oats	13.3	10.3	4.8	58.2	10.3	3.1
Wheat	13.4	12.1	1.9	69.0	1.9	1.7
Legumes.						
Beans	14.3	25.4	1.5	48.5	7.1	3.2
Peas	14.0	22.5	1.6	53.7	5.4	2.8
Oil Seeds.						
Cotton Seed, Egyptian	8.8	19.6	23.9	21.5	21.2	5.0
,, Bombay	8.5	17.9	19.4	29.9	20.0	4.3
,, Brazilian	9.4	21.1	23.2	25.0	17.0	4.3
Ground Nuts, earth or pea	7.0	29.7	49.2	12.2	6.0	2.8
Linseed	7.1	24.2	36.5	22.9	5.5	3.8
Palm Nut Kernels	8.4	8.4	48.8	26.8	5.8	1.8
Soya Beans	10.0	33.2	17.5	30.2	4.1	4.7
Sunflower Seed	7.5	14.2	32.3	14.5	28.1	3.4
Oil Cakes and Meals.						
Cocoanut Cake	9.2	23.7	8.2	42.0	11.0	5.9
Cotton Cake, Bombay	10.0	22.0	6.1	35.0	20.9	6.1
,, Brazilian	11.0	27.1	5.4	27.1	24.9	4.5
,, Egyptian	12.1	23.0	5.5	32.4	21.2	5.8
,, Decorticated	9.8	40.2	9.9	25.9	7.6	6.6
Cotton Seed Meal	8.7	42.1	10.9	24.9	7.4	6.0
Ground Nut Cake, Decorticated	9.4	47.5	7.1	25.6	4.6	5.8
,, Undecorticated	10.3	30.2	9.1	21.8	22.9	5.7
Linseed Cake, English made	11.2	29.5	9.5	35.5	9.1	5.2
,, Foreign	11.0	32.3	9.9	32.2	8.7	5.9
Linseed Cake Meal	11.8	35.7	3.1	33.9	9.0	6.5
Maize Germ Cake	9.5	15.1	6.9	57.9	5.3	5.3
,, Meal	10.5	23.1	11.7	49.8	5.4	1.0
Palm Nut kernel Cake, English	11.6	17.1	6.3	48.4	12.8	3.8
,, Imported	9.7	16.6	10.2	38.2	21.3	4.0
,, Extracted	15.0	19.0	2.0	51.0	9.0	4.0
Soya Bean Cake	14.5	42.4	7.0	25.8	5.0	5.3
,, Meal, Extracted	11.3	44.7	1.5	31.9	5.1	5.5
Bye Products.						
Barley, Brewer's Grains, Fresh	67.6	7.5	2.8	14.6	6.1	1.4
,, Dried	10.3	18.3	6.4	45.9	15.2	3.9
,, Distiller's Grains, Fresh	73.8	8.4	3.0	10.4	3.6	0.8
,, Dried	8.0	27.7	11.6	40.8	10.1	1.8
Maize, Gluten Feed	7.8	24.0	10.9	51.2	5.3	1.1
,, Gluten Meal	8.2	29.3	11.8	46.5	3.3	0.9
Wheat Offals :						
Pure Grades.						
Finest Grade, Fine Middlings	12.7	15.7	3.4	64.0	1.8	2.4
Second, Coarse Middlings or Sharps	13.5	16.4	5.0	56.2	5.3	3.6
Third, Pollards	13.3	14.3	4.8	55.6	7.7	4.3
Fourth, Bran	13.6	13.5	3.9	53.0	10.6	5.4
Mixed Grades.						
1st & 2nd Grades Mixed. Straight Run Middlings	13.1	16.0	4.5	59.6	3.9	2.9
2nd & 3rd ,, Pollards	13.7	16.3	5.3	54.5	6.2	4.0
1st 2nd & 3rd ,, Offals	13.8	15.7	4.7	58.0	4.5	3.3
Yeasts, Dried	12.1	49.3	2.9	30.4	0.1	5.2

METHODS USED IN AMERICAN PRACTICE.

Arthur L. Prince, M.Sc.

In case the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (A.O.A.C.) differ from the preceding British methods, a summary of the differences is given below, with additional notes.

A complete list of State Agricultural Colleges and Experiment Stations may be obtained from the U.S. Department of Agriculture, Washington, D.C.

A list of the Dominion Experimental Farms may be obtained from the Director, Experimental Farm, Ottawa, Canada.

Soil Analysis.

In view of the great variability in soils, it seems impossible at the present time to devise an entirely satisfactory method for sampling. It is obvious that the details of procedure should be determined by the purpose for which the sample is taken.

Sampling. Owing to the variations in the composition of the soil at different depths, it is essential that samples should always be taken to the same depth, and with a tool making a clean vertical cut. The sampling should be done when the soil is reasonably dry. The American method is to take samples which will be representative of the average depth of typically surface soil, usually about 7 ins., also composite samples from each distinctly different soil stratum to a depth of 40 ins., using a soil tube or auger, whichever may be best suited to the particular type of soil. It is recommended that the weight of a given volume of soil, as it lies in the field, be taken for calculating the percentage results obtained by analysis to pounds per given area of soil. Five or six points should be sampled along lines crossing the field in order to obtain as representative a sample as possible. The samples of each depth should then be thoroughly mixed and dried at ordinary temperature in a well-aired place. The dried soil is then pulverised to pass through a 1 mm. sieve, using a porcelain pebble mill or other suitable method which does not reduce the rock fragments. The sifted material is thoroughly mixed and preserved in a stoppered container. The detritus is weighed and discarded.

Loss on Ignition.

Method (1). (Approximate only for organic matter and not accurate for soils containing much combined water.) The soil upon which moisture has been determined is ignited in a platinum dish, stirring occasionally until organic matter is destroyed. If the soil contains appreciable quantities of carbonates, the residue is moistened, after cooling, with a few drops of a saturated solution of ammonium carbonate, dried, and heated to dull redness to expel the ammonium salts; the dish is allowed to cool in a desiccator and weighed. The percentage loss in weight is reported as organic matter.

Method (2). This method is described in A.O.A.C. (see also *J. Ind. Eng. Chem.*, 1918, **10**, 439.

Organic carbon. Special apparatus for estimating organic carbon is given in A.O.A.C.

Total Nitrogen.

The Kjeldahl method is often employed in preference to the Gunning-Hibbard method, which is similar to the British method. In the Kjeldahl method, 0.7 gram of mercuric oxide or 0.65 gram of mercury are used instead of the salt mixture; the digestion is continued until the mixture is practically colourless. The mixture is diluted when cool, 25 cc. of sulphide solution added (40 grm. commercial potassium sulphide per litre), and then an excess of sodium hydroxide solution (450 grm. of commercial sodium hydroxide in a litre of water). The distillation and titration of the ammonia are carried out in the usual manner.

Nitrates. The following methods are quoted from A.O.A.C. The solution is prepared by weighing 100 grm. of air-dried soil into a mortar or porcelain evaporating dish and adding with constant stirring 1 grm. of lime and 200 cc. of water. After allowing to settle for 10—20 mins., the mixture is filtered, a clear filtrate being essential.

In case the filtrate contains 6 parts or less of chlorine per million, procedure (A) is used; otherwise procedure (B) is used.

(A) The reagents necessary are:

Phenol disulphonic acid solution. 25 grm. of pure white phenol is dissolved in 150 cc. of concentrated sulphuric acid, 75 cc. of fuming sulphuric acid (13—15 per cent. SO_3) added, and the mixture heated at 100°C. for 2 hrs.

Standard nitrate solution. 0·722 grm. of pure potassium nitrate is dissolved in 1 litre of nitrate-free water. 50 cc.

of the nitrate solution is evaporated to dryness in a porcelain dish and treated with 2 cc. of the phenol disulphonic acid solution, rubbing with a glass rod to insure intimate contact. After diluting to 500 cc., 1 cc. is equivalent to 0·01 mgrm. of nitrogen as nitrate. This solution is stable, and standards for comparison are prepared by adding ammonium hydroxide solution to measured volumes of it contained in 100 cc. Nessler tubes.

25 cc. of the solution from the soil, prepared as above, is evaporated on a water-bath, allowed to cool, and 2 cc. of the phenol disulphonic acid solution added. After triturating thoroughly with a glass rod, 25 cc. of water is added, and then concentrated ammonium hydroxide or potassium hydroxide, drop by drop, with constant stirring, until a permanent yellow colour is obtained. The solution is compared in a colorimeter with the standard solution prepared in a similar manner as above.

(B) The reagents necessary are :

Aluminium foil (pure), cut into strips about 10 cm. long, weighing about 0·5 grm.

Sodium or potassium hydroxide solution. 250 grm. of pure hydroxide is dissolved in 1250 cc. of water, and two or three strips of aluminium foil added; after allowing to stand about 12 hrs., the solution is concentrated to 1 litre.

25 cc. of the solution from the soil, prepared as above, or such quantity as contains 0·1 mgrm. or less of nitrogen in the form of nitrate is placed in a 300 cc. casserole. 2 cc. of the sodium hydroxide solution is added, and the mixture is concentrated to about one-third of the original volume and then transferred to a 100 cc. test-tube, using nitrogen-free water and diluting, if necessary, to about 75 cc. A blank is prepared from 75 cc. of nitrogen-free water and 2 cc. of the sodium hydroxide solution in a 100 cc. test-tube. A strip of aluminium foil is placed in the test-tubes containing the sample and the blank, and the test-tubes are then closed with rubber stoppers and connected with other test-tubes containing about 50 cc. of slightly acidified ammonia-free water. After allowing sample and blank to stand for 12 hrs. at room temperature, or until reduction is complete, the traps are tested with Nessler solution ; if the traps contain the equivalent of only 1-2 cc. of standard ammonia solution, they should be disregarded ; if high in ammonia, indicated by frothing over of the sample, the determination should be

discarded. Sample and blank are transferred to distilling flasks, using 250 cc. of ammonia-free water for each, and the distillates examined with Nessler solution and compared with standards. After necessary correction for the blank, the mgrm. per litre of nitrogen in the form of nitrate is calculated.

Carbonates. Special apparatus for the determination is given in A.O.A.C.

Mineral Substances.

In order to obtain complete solution of the mineral substances of the soil, prior to the determination of silica, etc., the sodium carbonate fusion method is used as described in A.O.A.C. The fusion method is usually employed for the determination of total calcium and magnesium. If required, the ferric and aluminium and titanium oxides and phosphorus may be determined by following this procedure; their precipitation and removal is essential, prior to the determination of calcium and magnesium.

Phosphorus.

To determine total phosphorus, solution is effected either by the sodium peroxide fusion method or the magnesium nitrate ignition method, when the mineral substances become soluble in acid. After removal of the silica, the phosphorus is precipitated with ammonium molybdate solution. The yellow phosphomolybdate precipitate is filtered, washed with cold water, dissolved in standard potassium hydroxide solution, and the excess alkali titrated with standard nitric acid, using phenolphthalein as an indicator.

Available phosphoric acid. There is still considerable controversy as to the practical value of methods for estimating available phosphoric acid in soils. A.O.A.C. recommends a neutral solution of ammonium citrate as solvent in preference to citric acid. Fraps suggests 2N nitric acid (*J. Ind. Eng. Chem.*, vol. ii, No. 8, pp. 350—352). See also *Soil Science*, vol. xiii, No. 5, pp. 355—396.

Potash.

The fusion method using ammonium chloride and calcium carbonate has been adopted for total potash, precipitating as potassium platinichloride. Detailed directions are given in A.O.A.C.

Sulphur.

The new procedure for this determination is described in *J. Ind. Eng. Chem.*, 1923, **15**, 1183, and in A.O.A.C., based on fusing the soil with sodium carbonate and sodium peroxide.

Alkali salts. In semi-arid districts, soluble salts formed by decomposition of rock tend to accumulate and may reach toxic quantities; hence soils from such areas should be tested for saline material. The most common and dangerous " alkali salts " found in the U.S.A. are sodium chloride, carbonate and sulphate, and magnesium sulphate; large amounts of calcium sulphate are often associated with the other salts, but this seems to be harmless to plants, and experiments seem to show that its presence decreases the deleterious effects of magnesium sulphate. Sodium carbonate is the chief constituent of " black alkali," and when present in amount exceeding $0.05-0.1\%$ not only tends to corrode the plant just at the surface of the ground, but also destroys the granular structure of the soil by deflocculating the clay; the toxic effect of sodium bi-carbonate, however, is comparatively slight.

The most convenient method for rapidly estimating the " alkali " content is to use the electric bridge described in the *U.S. Bureau of Soils Bulletin,* No. 61. In case this instrument indicates that the " alkali " content is approaching the limits of toxicity, a complete analysis of the saline material should be made before releasing or condemning the soil for agricultural purposes.

The solution is prepared by shaking 25 grm. of the soil with 500 cc. of distilled water for 3 hrs. The filtrate is then analysed for calcium, magnesium, sodium, chlorides, sulphates, and carbonates.

For purposes of calculation, it is usual to assume that all the chloride is present in the form of sodium chloride. The sulphate present is then calculated as sodium sulphate, and the remaining sodium as sodium carbonate. In case calcium or magnesium are present in the solution, it will be found that there is an excess of sulphate present over that necessary to combine with the sodium; this remaining sulphate is then calculated as calcium sulphate, and the remainder as magnesium sulphate in case magnesium is also present. Calcium or magnesium sulphate is rarely found if sodium carbonate is present, as in such cases any calcium or magnesium in the soil would be in the form of insoluble carbonates.

For a detailed discussion of the limits of toxicity, the book by Dr. Harris on " Soil Alkali " should be consulted. Under normal conditions, the following appear to be the limits for ordinary farm crops : sodium carbonate, $0.05-0.1\%$; sodium chloride, $0.1-0.2\%$; sodium sulphate and magnesium sulphate, $0.7-1.0\%$.

Soil Reaction.

Although the litmus paper test for soil reaction is the only one described in the A.O.A.C., there are a large variety of tests now employed in American practice. Various modifications of the indicator method for determining pH are used as well as the electrometric method. County agents use the Truog method extensively; this method is based on the fact that when barium chloride and zinc sulphide are added to an acid, hydrogen sulphide is formed which may be estimated approximately by means of lead acetate paper (*Wis. Expt. Sta. Bull.* of 1915, p. 249). The Veitch method is widely used. (*J. Assoc. Off. Agl. Chem.*, Vol. III, No. 3.)

Mechanical analysis. A full description of the apparatus used for the mechanical analysis of soils by the U.S. Department of Agriculture is given in *Bureau of Soils Bulletin*, No. 84.

The U.S. Bureau of Soils has adopted the following limits of mechanical grades :—

Fine gravel	2 — 1	mm.
Coarse sand	1 — 0·5	,,
Medium sand	0·5 — 0·25	,,
Fine sand	0·25 — 0·10	,,
Very fine sand	0·10 — 0·05	,,
Silt	0·05 — 0·005	,,
Clay	less than 0·005	,,

The sample is air-dried, and after mixing thoroughly a sub-sample is taken by quartering; this is sifted through a 2 mm. sieve, any lumps present are crushed with a wooden rolling pin, care being taken not to crush any gravel into sand. The material passing through the sieve is dried at 100°C. for 2 hrs. in a flat-bottomed aluminium dish, allowed to cool in a dessicator, and a representative 5 grm. sample weighed out. This is placed in an 8 oz. sterilizer bottle, covered with 2 oz. of distilled water and about 5 drops of ammonia. A number of the sterilizer bottles are then placed in trays in a mechanical shaker for 7 hrs. ; longer or too vigorous shaking may erode the rubber stoppers and affect the analysis. The bottles are then removed from the shaking machine and placed upright in a rack, any material adhering to the stoppers being washed back. Each of the soils is in turn brought into suspension by using a compressed water jet containing a small percentage of ammonia. When sufficient time has been allowed for the sand to settle, as shown by examining a drop of the

liquid under the microscope, the supernatant liquid is poured off from the sterilizer bottle into a centrifuge tube. The sample is then centrifuged until no silt is left in suspension, as shown by examination under the microscope. The clay suspension is then poured into a large container, and the silt at the bottom of the tube again brought into suspension by means of the water-jet and centrifuged as before. This process is repeated until the water above the silt is clear after centrifuging. The number of washings necessary depends upon the amount of clay present; large amounts of clay are difficult to separate, although no separation is absolutely complete.

The sand separated above is transferred from the sterilizer bottle to a small platinum dish, dried on the steam-bath and then in an electric oven at 100°C., allowed to cool, and weighed. The sand is then separated by standard sieves into the five grades. The silt is transferred from the centrifuge tube to a platinum dish, dried and weighed. The clay may be determined either directly or indirectly, *i.e.*, by evaporating the liquid and actually weighing the residue, or by deducting the weight of silt *plus* sand from the total weight of the sample.

In making a mechanical analysis, the organic content of the soil is disregarded, as there is no satisfactory method of separating the organic matter without altering the soil structure or dehydrating the clay. The clay being usually equally divided among the different separates, this only causes a small error in the analysis of ordinary soils. It is evident, however, that little reliance can be placed upon the results of an analysis in the case of soils containing very high percentages of organic matter.

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PERCENTAGE COMPOSITION OF AMERICAN SOILS. (Abstr. U.S. Dept. Agric. Bull. 122.)

Nos. 1 and 2. Sand and loam. Coastal Plains province, viz.: Alabama, Florida, Louisiana, Mississippi, North Carolina, South Carolina, Texas, Virginia, Georgia, Oklahoma, Maryland, New Jersey.
Nos. 3–6. Loam and clay loam. Limestone Valley and Uplands province, viz.: Alabama, Tennessee, Arkansas, Missouri, Pennsylvania, Virginia, Kentucky, West Virginia.
Nos. 7–14. Silt loam. Glacial and Loessial province, viz.: Illinois, Indiana, Iowa, Kansas, Nebraska, Wisconsin, Kentucky, Ohio, Minnesota, New York. New Jersey. Maine.
Nos. 15–26. Clay, sandy loam, silt loam. Piedmont Plateau province, viz.: Alabama, Georgia, North Carolina, South Carolina, Virginia, Pennsylvania.

No.	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	K_2O	P_2O_5	SO_3	Ignition loss.	Water at 110°.	Organic matter
1	94.50	2.07	0.83	0.007	0.39	0.09	0.10	0.06	0.07	1.74	0.48	1.13
2	85.30	8.82	1.91	0.004	0.38	0.19	0.12	0.04	0.13	3.22	1.48	0.29
3	79.35	8.89	4.44	0.070	0.63	0.39	0.67	0.18	0.13	4.80	1.99	1.96
4	74.81	12.80	5.28	0.053	0.40	0.33	0.75	0.15	0.19	4.63	2.38	0.93
5	70.99	11.39	4.23	0.180	0.93	1.08	2.71	0.19	0.39	6.08	1.61	2.87
6	66.49	14.80	5.99	0.100	0.35	1.93	3.58	0.16	0.14	5.06	1.40	0.82
7	75.12	10.49	4.13	0.022	0.49	0.48	1.40	0.18	0.09	4.44	2.03	2.43
8	74.64	12.26	5.01	0.036	0.37	0.90	1.99	0.15	0.14	3.59	1.28	0.60
9	73.61	9.67	3.54	0.120	1.08	0.77	2.28	0.22	0.17	7.44	2.94	4.29
10	71.43	13.44	4.28	0.104	1.40	1.28	2.03	0.16	0.14	5.56	4.12	2.72
11	65.68	14.15	5.67	0.068	1.36	0.83	2.16	0.15	0.17	9.52	3.39	7.07
12	73.80	13.24	4.37	0.072	1.19	0.39	2.22	0.11	0.03	3.13	1.18	1.39
13	73.50	9.10	4.30	0.113	0.94	0.71	2.03	0.24	0.13	7.70	2.75	4.94
14	76.86	9.49	3.79	0.062	0.93	0.58	1.04	0.20	0.18	4.76	2.03	2.62
15	66.49	17.11	7.43	0.51	0.36	0.31	0.62	0.17	0.07	8.06	2.47	1.26
16	44.15	27.58	16.23	0.033	0.44	0.09	0.61	0.15	0.07	11.83	2.90	0.27
17	88.57	5.76	1.55	0.044	0.39	0.21	0.82	0.08	0.04	2.93	0.53	1.46
18	55.69	24.42	8.83	0.022	0.40	0.29	1.06	0.07	0.09	8.94	2.00	0.09
19	80.79	10.55	1.61	0.017	0.89	0.19	3.96	0.12	0.06	1.41	0.48	0.40
20	69.35	18.04	3.42	0.014	0.72	0.29	3.34	0.12	0.06	4.54	1.53	0.33
21	76.71	12.85	2.81	0.005	0.08	0.29	3.26	0.05	0.12	3.16	0.47	1.78
22	74.38	16.31	2.56	0.005	0.21	0.38	4.07	0.05	0.14	2.80	0.22	0.41
23	84.58	5.54	3.30	0.045	0.21	0.25	0.74	0.12	0.15	3.89	0.92	2.40
24	74.99	10.90	6.75	0.039	0.26	0.32	0.97	0.15	0.16	4.72	1.43	1.04
25	74.33	11.00	4.64	0.136	1.13	0.69	1.57	0.16	0.15	4.51	1.72	1.99
26	71.76	14.36	5.82	0.109	1.73	1.06	1.50	0.10	0.10	2.83	2.06	1.21

A 2

Analysis of Manures.

Directions for Sampling. (See A.O.A.C.)
Preparation of Sample.

The entire sample is passed through a 10-mesh sieve previous to its subdivision for analysis. The gross sample is reduced by quartering to a quantity sufficient for analytical purposes. This is passed through a 1 mm. mesh sieve, breaking up the lumps as necessary.

Determination of Nitric and Ammoniacal Nitrogen.

One gram of the sample is placed in a 500 cc. flask with about 30 cc. of water and 2-3 grm. of reduced iron. 20 cc. of sulphuric acid (1:1), are added, and the mixture allowed to stand until the violence of the reaction has moderated. The solution is boiled for 5 mins., allowed to cool, and then distilled as usual with magnesium oxide.

In the analysis of nitrate salts, the above procedure is followed, except that 25 cc. of the nitrate solution (equivalent to 0.25 grams of the sample) is used with 5 grm. of reduced iron.

The Devarda method is frequently used, reduction and distillation being carried on at the same time. 0.5 grm. of the nitrate, 300 cc. of water, 3 grm. of Devarda alloy, and 5 cc. of 42 per cent. sodium hydroxide are distilled in a 200 cc. flask, using methyl red as an indicator.

Alternative methods and methods for the estimation of water-insoluble organic nitrogen are given in A.O.A.C.

Organic Nitrogen.

Several arbitrary methods are in vogue for estimating the available organic nitrogen in fertilizers. These methods yield only approximate results, and are intended to give some insight into the nature of the organic nitrogen.

(*a*) Water-insoluble organic nitrogen soluble in neutral permanganate. Soluble organic and inorganic nitrogen are eliminated by washing, and the residue treated with 2 per cent. permanganate solution; after ½ hr. on the steam bath, the residue is filtered, washed, and nitrogen content determined. This nitrogen represents the inactive water-insoluble organic nitrogen; subtracted from the total nitrogen *minus* the water-soluble nitrogen, the result gives the water-insoluble organic nitrogen soluble in neutral permanganate.

(*b*) Water-insoluble organic nitrogen distilled from alkaline permanganate. After being washed with water, the material is digested for $\frac{1}{2}$ hr. with alkaline permanganate, and the nitrogen distilled over as ammonia. This nitrogen represents the active insoluble organic nitrogen.

Determination of phosphates.

(*a*) Phosphates soluble in water. 2 grm. of the sample is placed on a 9 cm. filter paper and washed with successive small portions of water, allowing each portion to pass through before adding more, until the filtrate measures about 250 cc. If the filtrate is turbid a small amount of nitric acid is added. The solution is then made up to a convenient volume, and an aliquot portion used for the determination of the phosphoric acid by the molybdate method, as described below.

(*b*) Phosphates insoluble in ammonium citrate. The ammonium citrate solution is prepared as follows : 370 grm. of commercial citric acid is dissolved in 1500 cc. of water; the solution is then nearly neutralized with ammonium hydroxide, allowed to cool, and made exactly neutral to corallin (saturated alcoholic solution) by adding dilute ammonium hydroxide very slowly. The solution is then diluted to Sp. Gr. 1·09 at 20°C. The soil is digested in this solution as follows : 100 cc. of the citrate solution is heated to 65°C. in a 250 cc. flask, placed in a warm water-bath and covered loosely to prevent free evaporation. The filter containing the washed residue from (*a*) is dropped into the flask, which is then closed tightly with a rubber cork and shaken violently until the filter paper is reduced to pulp, relieving the pressure by momentarily removing the stopper. The sample is digested at 65°C. for exactly 30 mins., shaking every 5 mins. The contents of the flask are then filtered as quickly as possible, and the filter washed with water at 65°C. until the volume of the filtrate is 350 cc. The filter and its contents are transferred to a crucible, and ignited to remove all organic matter ; the residue is then digested with 10—16 cc. of concentrated hydrochloric acid until all the phosphate is dissolved. The solution is diluted to 200 cc., filtered through a dry filter, and an aliquot portion used for the phosphoric acid determination by the molybdate method as below.

(*c*) Total phosphoric acid. 2 grm. of the sample is ignited to expel any organic matter present, and the residue dissolved in hydrochloric acid ; any silica present must be removed. The solution is then diluted to 200 cc., and poured through a dry filter. An aliquot portion of the solution corresponding

to 0·25 grm., 0·50 grm., or 1 grm. is used for the phosphoric acid determination by the molybdate method.

(*d*) Molybdate method. An aliquot portion of the solution prepared as in (*a*), (*b*) or (*c*) is neutralized with ammonium hydroxide and cleared by addition of a few drops of nitric acid. In case hydrochloric acid or sulphuric acid has been used as a solvent 15 grm. of dry ammonium nitrate should be added. The solution is then heated to about 65°C., and molybdate solution added (70 cc. for each 0·1 grm. phosphoric acid present), digesting at this temperature for 1 hr. The phosphoric acid has been completely precipitated if the supernatant liquid remains clear on the addition of a few drops of molybdate solution. The precipitate is filtered, washed with ammonium nitrate solution, and dissolved by washing into a beaker with 100 cc. of warm water containing sufficient ammonium hydroxide. This solution is nearly neutralized with hydrochloric acid, allowed to cool, and magnesia mixture is added slowly from a burette with vigorous stirring (15 cc. of magnesia mixture for each 0·7 grm. phosphoric acid present). After 15 mins., 12 cc. of ammonium hydroxide (Sp. Gr. 0·90) is added, and the beaker allowed to stand until the supernatant liquid is clear. The precipitate is filtered, washed with dilute ammonium hydroxide until the washings are practically free from chlorides, ignited, and weighed as magnesium pyrophosphate.

The solutions used in the above method should be prepared as follows :

Molybdate solution. 100 grm. of molybdic acid is dissolved in a mixture of 144 cc. of ammonium hydroxide (Sp. Gr. 0·90) and 271 cc. of water. This solution is poured slowly and with constant stirring into a mixture of 489 cc. of nitric acid (Sp. Gr. 1·42) and 1148 cc. of water. The mixture is kept in a warm place for several days, decanted from any sediment, and preserved in glass-stoppered bottles.

Ammonium nitrate solution. 200 grm. of commercial ammonium nitrate, phosphate free, is dissolved in water and diluted to 2 litres.

Magnesia mixture. 22 grm. of recently ignited calcined magnesia is dissolved in dilute hydrochloric acid, avoiding an excess of the acid. A small excess of calcined magnesia is added, and the mixture boiled for a few minutes to precipitate any iron, aluminium or phosphoric acid. After filtering, 280 grm. of ammonium chloride and 261 cc. of ammonium hydroxide (Sp. Gr. 0·90) are added, and the solution diluted to 2 litres.

Dilute ammonium hydroxide for washing should consist of

100 cc. of ammonium hydroxide (Sp. Gr. 0·90) diluted to 1 litre.

Boric Acid.

In recent years borax has been found in fertilizers to a considerable extent. Water soluble and acid soluble boric acid are determined ; see A.O.A.C.

Analysis of Feeding Stuffs.

Preparation of sample.

The sample is ground so that it will pass through a sieve having circular openings 1 mm. in diameter; if the material cannot be ground it must be reduced to as fine a state as possible.

Determination of moisture.

A quantity representing about 2 grm. of the dried material is dried *in vacuo* at 100°C. to constant weight (approximately 5 hrs.). Directions for drying *in vacuo* without heating are given in A.O.A.C.

Determination of oil.

Large quantities of soluble carbohydrates in the material may interfere with the complete extraction of the fat, and should therefore be extracted with water before proceeding with the determination. 2 grm. of the material is extracted with washed, redistilled ether in a Soxhlet apparatus for 16 hrs. The extract is dried at 100°C. for 30 mins., allowed to cool in a dessicator, and weighed. The drying for 30 mins. and weighing is continued alternately until a constant weight is reached, which for most materials requires a period of 1-1½ hrs.

Carbohydrates. Methods for the determination of sugars are given in detail in A.O.A.C.

DAIRY PRODUCTS.

G. D. Elsdon, B.Sc., F.I.C., and A. Douglas Heywood, F.I.C.

Examination and Analysis of Milk.

The average composition of genuine cows' milk is as follows :—87·35% water, 3·75% fat, 8·90% solids-not-fat. The percentage of solids-not-fat generally consists of : milk sugar, 4·7 ; casein, 3·0 ; albumen, 0·4 ; ash, 0·75 ; other constituents, 0·05. The maximum and minimum figures recorded for fats are 12·52% and 1·04% ; for solids-not-fat 10·60% and 4·90%

Figures showing the average composition of milk have been given by Richmond in the *Analyst* for many years up to 1914 (see also *Analyst*, 1917. **42**, 118 ; 1920, **45**, 138). For Egyptian cow's milk, see Hogan and Azadian (*Ibid.*, 1919, **44**, 168). For the composition of buttermilk, see Hodgson (*Ibid.*, 1919, **44**, 229).

The evening milk usually contains 0·2—0·7% more fat than the morning milk ; the fat is usually at its lowest in May and June, and at its highest in November ; the solids-not-fat are usually somewhat lower in July and August. The relationship of milk sugar to proteins (casein and albumen) and to ash in genuine normal milk generally approaches the ratio 13 : 9 : 2.

CORRECTION OF SPECIFIC GRAVITY OF MILK FOR TEMPERATURE (Chr. Müller).

Sp. Gr. (Water =1000)	Temperature of Milk °C.										
	10	11	12	13	14	15	16	17	18	19	20
1014	13.4	13.5	13.6	13.7	13.8	14.0	14.1	14.2	14.4	14.6	14.8
15	14.4	14.5	14.6	14.7	14.8	15.0	15.1	15.2	15.4	15.6	15.8
16	15.4	15.5	15.6	15.7	15.8	16.0	16.1	16.3	16.5	16.7	16.9
17	16.4	16.5	16.6	16.7	16.8	17.0	17.1	17.3	17.5	17.7	17.9
18	17.4	17.5	17.6	17.7	17.8	18.0	18.1	18.3	18.5	18.7	18.9
19	18.4	18.5	18.6	18.7	18.8	19.0	19.1	19.3	19.5	19.7	19.9
20	19.3	19.4	19.5	19.6	19.8	20.0	20.1	20.3	20.5	20.7	20.9
21	20.3	20.4	20.5	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0
22	21.3	21.4	21.5	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0
23	22.3	22.4	22.5	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0
24	23.3	23.4	23.5	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0
25	24.2	24.3	24.5	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.0
26	25.2	25.3	25.5	25.6	25.8	26.0	26.2	26.4	26.6	26.9	27.1
27	26.2	26.3	26.5	26.6	26.8	27.0	27.2	27.4	27.6	27.9	28.2
28	27.1	27.2	27.4	27.5	27.8	28.0	28.2	28.4	28.6	28.9	29.2
29	28.1	28.2	28.4	28.6	28.8	29.0	29.2	29.4	29.6	29.9	30.2
30	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4	30.6	30.9	31.2
31	30.0	30.2	30.4	30.6	30.8	31.0	31.2	31.4	31.7	32.0	32.3
32	31.0	31.2	31.4	31.6	31.8	32.0	32.2	32.4	32.7	33.0	33.3
33	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.7	34.0	34.3
34	32.9	33.1	33.4	33.5	33.8	34.0	34.2	34.4	34.7	35.0	35.3
35	33.8	34.0	34.2	34.4	34.7	35.0	35.2	35.4	35.7	36.0	36.3

Specific gravity.

This may be determined by means of a delicate hydrometer or a Westphal balance. The specific gravity of genuine milk generally falls between 1·029 and 1·034 at 15·5°C. In case the gravity is taken at another temperature, it may be corrected by means of the above table. In correcting specific gravity for temperature it is generally sufficient to add or subtract 0·0002 for each degree over or under 15°C.

The samples should be shaken gently just before taking the specific gravity, in order to mix in the cream, but care must be taken to avoid the formation of air bubbles.

The specific gravity of milk is raised by the abstraction of fat, and lowered by the addition of water; hence by partial skimming and watering an adulterated sample may possess the same gravity as that of genuine milk. It is therefore necessary to estimate the fat and total solids.

Determination of total solids and ash

About 5 grm. of milk are measured out into a weighed platinum or porcelain dish from a pipette, and the whole is again rapidly weighed. The dish is placed on a boiling water bath until the solids are apparently dry, and then heated in the water-oven for three hours, cooled in the desiccator and weighed to obtain the total solids.

The ash is preferably estimated on at least 10 grm. of the milk. The solids are ignited at as low a temperature as possible, the flame (*e.g.* a luminous Argand burner) being placed some distance below the dish, to avoid volatilisation of chlorides.

When the milk is sour it should be neutralised to phenolphthalein with N/10 caustic soda or strontia before evaporation, the weight of solids being corrected for the amount of alkali added. The total solids will be low on account of the production of volatile products during the decomposition, but suitable corrections may be made (see Richmond and Miller, *Analyst*, 1906, **31**, 317; Richmond, "Dairy Chemistry," 2nd edition, p. 319; compare also the maceration method for fat, below).

Determination of fat.

Adams' method. A pipette is graduated to deliver 5 grm. of milk (Sp. Gr. 1·032) on draining for 45 secs.; such a pipette would deliver 4·82 grm. of water. In actual practice the amount of any particular milk delivered is usually weighed in the estimation of the total solids, and if it differs materially from 5 grm. the difference may be allowed for. 5 grm. of the milk are delivered from the pipette on to the special "Adams' coil," which is then allowed to dry in the air overnight (Richmond recommends drying in the water-oven). The coil is rolled up and placed in a Soxhlet extractor fitted

with a double surface condenser and with a small tared flask. Ether is then poured into the Soxhlet tube until there is rather more than necessary to syphon over, and the flask gently heated on the water-bath for 2½ hrs. At the end of this time, when the ether has just syphoned over into the flask, the coil is removed from the tube, the distillation continued, and all the ether allowed to collect in the tube, as there is not sufficient ether to fill up to the top of the syphon when the coil is removed. The flask is then removed, and a few drops of ether and of absolute alcohol added, after which it is dried in the steam-oven for 1½ hrs. and weighed. The coils themselves give a slight residue; this is estimated on several coils out of each delivery and subtracted from the weight of fat obtained. Before use the coils should be extracted for at least half an hour with ether. In the case of coils which are not sold as "fat-free" they should be extracted for 3 hrs. with alcohol containing 10% of acetic acid, and then the flask changed and the coils extracted for half an hour with alcohol, placing a small quantity of anhydrous sodium carbonate in the flask; a further extraction for half an hour with ether is an advantage.

The Adams' method is unsuitable for sour milk.

The Gerber method. This process requires special apparatus, including a special type of centrifuge and tubes. 10 cc. of sulphuric acid (Sp. Gr. 1·820—1·825) are measured into one of the butyrometer tubes, and then 11 cc. of the milk allowed to run down the sides of the butyrometer and to float on the surface of the acid; the pipette is allowed to drain 4 secs., and then touched on the surface of the liquid or on the neck of the tube. 1 cc. of amyl alcohol is then added, the stopper inserted, and the butyrometer well shaken. The butyrometer is inverted two or three times, so that any acid in the neck may be thoroughly mixed with the liquid; it is then placed in water at 70°C. for 5 mins., when it is ready for whirling. The tube should be whirled for about 3 mins. at full speed, and not stopped suddenly. The tube is then placed in water at 70°C. for a few minutes before reading the volume of the fat, which is taken from the bottom of the upper meniscus to the separating line.

In calibrating the tubes 0·8 large divisions are equal to 0·1 cc. The pipette should deliver 11·02 grm. of water.

The Röse-Gottlieb method. A stoppered cylinder, or preferably a light flat-bottomed stoppered tube about 7 ins. long and of a uniform width of about 1 in. is weighed. 5 cc. of the milk are pipetted into it and again weighed. 0·5 cc. of 15% ammonia is added and mixed with the milk by rotating the tube. 5 cc. of alcohol (methylated spirit free from petroleum) are added, and the liquids well mixed by a rotary

motion, avoiding splashing on to the stopper. 12·5 cc. of ether are added in small quantities with constant rotary shaking as before, and then 12·5 cc. of petroleum ether (b.pt. below 60°C.) introduced, and the stopper inserted loosely. The tube is then partially immersed in a water-bath at about 60°C. until ether begins to condense on the stopper when the tube is removed from the water-bath, the stopper inserted tightly, and the tube cooled under the tap and thoroughly shaken. When the liquid has separated into two perfectly clear layers the stopper is removed, wash-bottle tubes inserted, and the ether-layer blown off to within $\frac{1}{8}$ in. into a small tared flask. 25 cc. of a mixture containing 50% ether and 50% petroleum ether are added, and the extraction repeated. In the case of an ordinary milk three such extractions are sufficient. The mixed ether solutions are evaporated, and the residue dried in the water-oven to a constant weight. The fat is then removed by washing several times with a small amount of petroleum ether and the flask again weighed, the loss being fat. The method may be used, taking suitable quantities, for ordinary milk, sour milk, condensed or dried milks (sweetened and unsweetened), cream and cheese.

The Maceration method. This process was originally devised by Bell. The method as modified by Richmond is substantially as follows, and is essentially the same. (*Analyst,* 1906, **31**, 317.)

About 10 grm. of milk are weighed into a flat-bottomed platinum basin, about 3 ins. diam. and slightly over 1 in. high, and provided with a flat-ended glass stirrer. Two drops of a 0·5% solution of phenolphthalein are added, and approximately N/11 strontia solution added until a faint pink colour appears. The contents are evaporated to a damp paste on the water-bath, when the basin is transferred to a hot plate, and the paste mixed with the stirrer; at a certain point in the evaporation, the paste detaches itself from the basin; and by careful manipulation both basin and stirrer can be obtained practically clean. On further evaporation with stirring the paste gradually attains a state in which it may be crushed, and at this stage it is removed from the hot plate and about 20 cc. of methylated ether (Sp. Gr. 0·720, dried over calcium chloride) are added. By gentle rubbing with the stirrer the solids are crushed; the basin and stirrer are now scraped with a spatula to bring any small portions of solids adhering to the sides under the ether, and the solids are gently rubbed to a powder. The ether is decanted through a weighed filter-paper, and the solids again treated with ether. The ethereal solution is allowed to settle, and the ether decanted through the filter. Without any

further addition of ether the solids are now ground to a very fine powder, with the small amount of ether in the basin, so that the larger portions remaining may more readily be seen. A further addition of ether is made, and the solids again ground; at this stage the solids take some minutes to settle sufficiently to allow the decantation of the ether. After about six or eight treatments in this manner the solids are allowed to dry in the air, the portions clinging to the stirrer and sides of the basin detached, and 5 cc. of alcohol and a few drops of water are added; the solids are well mixed with the alcohol, and the basin is placed on the hot plate and evaporated until the paste begins to break up, when the solids are again treated as before. A second treatment with alcohol and a further six to eight extractions with ether are given. The solids are dried in the air, and then in the water-oven to constant weight (0·00428 grm. is subtracted for the equivalent of each cc. of $N/10$ strontia used). The mixed ethereal solutions are distilled, and the residue weighed; the fat is extracted with petroleum ether, and the small insoluble residue subtracted from the total (the residue usually consists of phenolphthalein, and its weight may be neglected without appreciable error).

Calculation of results. The presence of fat in milk tends to lower its specific gravity, while the presence of solids not fat tends to raise it; therefore there must be a relation between the gravity, fat and total solids which will enable the third factor to be calculated if the other two are known.

Various formulæ have been used whereby one factor may be calculated when the other two are known. The formula of Hehner and Richmond is :—

$$T = 0·254G + 1·164F.$$

This has been modified by Richmond as follows :—

$$T = 0·25G + 1·2F + 0·14,$$

where $T = \%$ total solids; $G =$ specific gravity $- 1000$ (Sp. Gr. water $= 1000$); $F = \%$ fat. The calculation may be performed from Hehner and Richmond's table or by means of Richmond's slide rule.

Further details on the calculation of results are given by Harris (*Analyst*, 1918, **43**, 263, 345, 375; 1919, **44**, 43, 314), Richmond (*Ibid.*, 1919, 44, 209), and by Hodgson (*Ibid.*, 1920, **45**, 91).

Determination of proteins.

Kjeldahl's method. 10 grm. of milk, 25 cc. of pure sulphuric acid, a small crystal of copper sulphate, and 10 grm. of potassium sulphate are placed in a Kjeldahl flask and the whole boiled until colourless. The solution is then cooled, diluted, and the ammonia determined by distillation in the usual manner. The number of cc. of $N/10$ hydrochloric acid

used, multiplied by 0·014, gives the percentage of nitrogen, or multiplied by 0·08932, gives the percentage of proteins. The Kjeldahl process is described in greater detail under "Ultimate Analysis."

Aldehyde figure. 10 cc. of milk, neutralised to phenolphthalein with caustic soda and then mixed with 2 cc. of 40% formaldehyde solution, is titrated until neutral with N/10 strontia. The acidity due to the formaldehyde (separately determined) is subtracted. The acidity developed by the formaldehyde, calculated as degrees, gives the aldehyde figure. The strontia figure is about 1.1 times that given by N/10 soda. The aldehyde figure from strontia multiplied by 0.170 gives percentage of proteins.

Determination of acidity.

10 cc. of milk are placed in a 100 cc. extraction flask with 10 cc. of water and 1 cc. of 0·5% phenolphthalein solution, and titrated with N/10 soda until a faint pink colour is obtained. This may be matched against the colour produced by 1 drop of a 0·01 per cent. solution of rosaniline acetate in 96% alcohol in the same amount of milk, etc. Each cc. of N. alkali used per litre of milk is called 1° of acidity.

Determination of milk sugar.

Wiley's method. 3 cc. of mercuric nitrate solution (prepared by dissolving 5 cc. of mercury in 96 cc. of strong nitric acid and diluting with an equal volume of water) are added to 100 cc. of milk, the liquid mixed thoroughly, filtered, and the rotation read in a 200 mm. tube.

$$\text{\% anhydrous lactose} = \frac{a}{1 \cdot 11 \times G} \times \frac{100 - (F \times 1 \cdot 075 \times G)}{100}$$

where a = observed rotation, G = Sp. Gr. of milk in lactometric degrees, and F = % of fat, or;

$$\text{\% anhydrous lactose (approx.)} = a \times 0 \cdot 84.$$

Reduction method. 10 cc. of milk are made up to about 80 cc. with water, just neutralised with N/10 NaOH, and Fehling's solution A added drop by drop until a flocculent precipitate forms and settles, leaving a clear solution. The solution is then made up to 100·67 cc., well mixed, and filtered (the 0·67 cc. is to allow for the volume occupied by the proteins and fat). The process is then continued as described in the sections on carbohydrates (cf. *Analyst*, 1919, **44**, 408).

$$\text{\% anhydrous lactose (approx.)} = \text{CuO} \times 0 \cdot 64.$$

Detection of colouring matters.

Aniline colours may be detected by the production of a pink colour on addition of concentrated hydrochloric acid to the milk. Vegetable dyes may be detected by making alkaline with sodium carbonate, and immersing a strip of filter paper. The filter paper may be tested as follows : after allowing to

stand overnight annatto gives a pink colour with one drop of concentrated sulphuric acid; methyl orange behaves in the same manner, but is bleached by stannous chloride solution. (*cf.* Lowe, *Analyst*, 1925. **50**, 335.)

The addition of colouring matter to milk is prohibited by Section 4 of the Milk and Dairies (Amendment) Act, 1922.

Detection and determination of boric acid.

Detection. A few drops of milk are placed in a depression in a spot plate, and one drop of turmeric tincture and a drop of dilute hydrochloric acid added. The tile is warmed on the water-bath until the milk is dry; in the presence of boric acid a pink colour will be developed.

Determination. 70 cc. of milk are added to 7 cc. of approx. 3N. NaOH in a 3 in. flat-bottomed platinum dish and evaporated on the water-bath, the skin which forms being periodically removed to the side. A flame is applied to the side of the dish, care being taken that the contents do not froth over; the ignition is completed at a high temperature until the ash is almost white. The dish is cooled, and 35 cc. of water are added and allowed to stand until the melt is disintegrated, when it is filtered into a 100 cc. flask. 5 cc. of approx. 3N. hydrochloric acid and 15 cc. of water are added to the dish and the solution again filtered through the same filter into the same flask. The dish is further treated with 4 cc. of 3N. hydrochloric acid and 16 cc. of water, and again filtered. To the mixed filtrates 7 cc. of calcium chloride solution (10%) and phenolphthalein are added, and then N/1 NaOH is added until a slight permanent pink coloration is produced. The liquid is diluted to the mark and filtered into a graduated cylinder. 80 cc. of the filtrate are made slightly acid to methyl orange with hydrochloric acid and boiled to eliminate carbon dioxide. The solution is cooled and titrated with N/10 sodium hydroxide until neutral to methyl orange. 30 cc. of glycerol or 10 grm. of mannitol are added and the titration continued until the solution is neutral to phenolphthalein. The acidity due to 30 cc. of glycerol is determined and subtracted from the number of cc. of N/10 sodium hydroxide used after the addition of the glycerol; the difference multiplied by 0·011 gives the percentage of boric acid in the milk. In case the amount of sodium hydroxide used exceeds 1 cc., a portion of the boric acid will be precipitated together with the calcium phosphate. In this case the precipitate is washed with 25 cc. of water through a hole made in the filter paper, 5 cc. of 3N. hydrochloric acid, a further 25 cc. of water, 0·5 cc. of calcium chloride solution and phenolphthalein are added to the filtrate, and the liquid titrated with N. sodium hydroxide until just pink. The solution is diluted to 100 cc., filtered, and 80 cc. titrated as before. The amount of boric

acid so found is added to that found in the first preciptation after making the necessary correction for dilution.

Richmond and Miller's method. A mixture of 20 cc. of milk and 10 cc. of a 0·5% solution of phenolphthalein is titrated with N/10 caustic soda until pink, boiled, made faintly acid, and finally made faintly alkaline with N/10 caustic soda while still boiling. 30 cc. of glycerol are added, and the titration continued until the pink colour returns, without further heating. The number of cc. of N/10 caustic soda used (less that required by the glycerol) multiplied by 0·0031 gives the percentage of boric acid (*Analyst*, 1907, **32,** 151).

Detection and estimation of formaldehyde.

- *Detection.* Hehner's reagent for the detection of formaldehyde is prepared by mixing 25 cc. of 5% ferric chloride solution and 1 litre of concentrated sulphuric acid. 2–3 cc. are placed in a small test-tube and about 5 cc. of the milk added carefully so that it forms a layer above the acid. In the presence of formaldehyde a violet coloration will be produced on standing. It has been stated that the presence of nitrites interferes with this reaction (*Analyst*, 1912, **37,** 155, 178), but Elsdon and Sutcliffe do not agree with this statement (*Analyst*, 1913, **38,** 452).

If the Gerber or Babcock method for the estimation of fat is used and ferric sulphate is added to the acid used, in proportion to the amounts indicated above, formaldehyde will produce a violet coloration on shaking the tube. If nitrates or nitrites are present, a bright golden-brown colour is produced (*Analyst*, 1913, **38,** 452). Nitrites may be detected by adding 1 or 2 cc. of Griess-Ilosvay solution (see " Special reagents ") to 5 cc. of milk; a pink colour developing in less than a quarter of an hour indicates nitrites.

Estimation. In the method of Shrewsbury and Knapp (*Analyst*, 1909, **34,** 12), the reagent is made by mixing 100 cc. of concentrated hydrochloric acid with 1·6 cc. of N/1 nitric acid. 10 cc. of the freshly made reagent are added to 5 cc. of the milk in a test-tube, the mixture shaken vigorously and kept for 10 mins. in a water-bath at 50°, and then rapidly cooled. As the violet colour produced varies in intensity according to the amount of formaldehyde present, the formaldehyde may be estimated by comparison with standards. If the colour obtained is deeper than that shown by 6 parts of formaldehyde per million of milk, the sample should be diluted with pure milk. The most delicate quantitative reaction is obtained with milks containing 0·2 to 6 parts per million of formaldehyde. In case nitrites are present, 5 cc. of the milk are treated with 0·05 grm. of urea and 1 cc. of N/1 sulphuric acid, and the mixture heated in the boiling water-bath for 2 mins. and then cooled; the Shrewsbury and Knapp

method may then be performed in the usual way on the resulting liquid (Monier-Williams).

Detection of salicylic acid.

The milk is shaken with 10 vols. of water, filtered, and 1% ferric chloride solution is added drop by drop to the filtrate, when 0·01% of salicylic acid gives a brownish-purple colour.

Detection and determination of benzoic acid.

Detection. 25 cc. of milk are heated with an equal volume of hydrochloric acid until the precipitate is completely dissolved. The cooled mixture is shaken with 25 cc. of a mixture of two volumes of petroleum spirit and one volume of ether. The " ethereal " solution is separated and one drop of concentrated ammonia solution added. A precipitation of ammonium benzoate takes place in the " ethereal " solution if benzoic acid be present. As a confirmatory test 5 cc. of water are added to the " ethereal " solution, the mixture is shaken, the aqueous layer separated, heated for a few minutes on the water-bath to expel excess of ammonia, and tested for benzoic acid with ferric chloride in the usual manner.

Determination. 20—25 cc. of milk are heated with an equal volume of hydrochloric acid, under a reflux condenser if necessary. The cooled mixture is extracted three times with an equal volume of a mixture of equal parts of ether and petroleum spirit; the mixed separated " ethereal " layers are rendered alkaline with ammonia solution, 10 cc. of water added, and the mixture shaken; the aqueous layer is separated and the extraction repeated twice, keeping alkaline with ammonia if necessary. The mixed aqueous portions are made alkaline with hydrochloric acid, and extracted three times with 20 cc. of the mixture of ether and spirit as before. The final mixed " ethereal " solutions are allowed to evaporate spontaneously and dried in the desiccator until constant in weight. The benzoic acid is then driven off by heating to 100°C., and the loss on heating gives the amount of benzoic acid present. (Hinks, *Analyst*, 1913, **38**, 555)

Determination of sediment.

The volume of sediment in milk may be estimated by placing about 500 cc. in a tall cylindrically-shaped vessel, to the bottom of which is attached a glass tube with its bottom end drawn out to a fine bore, such that 0·5 cc. occupies between 5 and 6 cm. of the tube, the tube being graduated in 100ths of a cc. The milk is allowed to stand for several hours, preferably overnight, with the addition of a small amount of formaldehyde to prevent the milk from souring; the volume of the sediment is then noted. A limit of not more than 2 vols. of sediment per 100,000 of milk has been suggested. If the volume of sediment is large, its nature

should be determined by means of the microscope (see Lowe, *Chemical News*, 1912, **105**, 61).

The presence of cow dung may be shown by Pettenkofer's test for bile salts, which is carried out as follows:—The sediment is removed to a watch-glass and stirred with a few drops of a solution of cane sugar, the whole being then dried on the water-bath. A drop of concentrated sulphuric acid added to the film will show a reddish-purple colour in the presence of bile salts.

Adulteration of Milk.

Milk may be adulterated by the addition of water, the extraction of fat, or the addition of preservatives. If the fat falls below 3% or the solids-not-fat below 8·5%, adulteration is presumed, the proof to the contrary resting with the vendor (Sale of Milk Regulations, 1901). The Milk and Cream Regulations (1912 and 1917) prohibit the addition of any preservatives to milk. The " Milk (England and Wales) Order, 1921," states that dried or condensed milks may not be sold as " milk " after dilution with water, that " Grade A " (*i.e.*, milk of a special standard of hygienic quality) shall only be sold under license from the Ministry of Health, and that colouring matter or water shall not be added to milk or cream. The amending order (1920, No. 1056) states that " For the purposes of this Order the expression ' milk ' shall include skimmed, separated and buttermilk, and any milk which has been submitted to any one or more of the following processes, viz.:—sterilization, pasteurization, homogenization, or any other like process, but shall not include condensed milk."

The Milk and Dairies (Amendment) Act, 1922, prohibits the addition of colouring matter or water or any dried or condensed milk or any fluid reconstituted therefrom or any skimmed milk or separated milk to milk intended for sale.

Richmond suggests a multiple standard of 8·5% of solids-not-fat: 4·5% of milk sugar, 0·5% of total nitrogen (=3·19% of proteins), and 0·70% of ash. Ash insoluble in hot water should not be less than 0·50%. Compare also the Milk and Dairies (Consolidation) Act, 1915, and the Commencement of Operation (No. 704) Order, 1925. " A milk should never be pronounced as watered on the evidence of the solids-not-fat alone—unless this is well below 8·0%. A determination of the milk sugar, total nitrogen and ash should be made in addition; a judgment formed on these three determinations will in all probability be correct, and if the figures for at least two of them are above the limit, the milk is probably genuine."

Richmond's table shows that the ash in abnormal milks never falls below 0·70%, and that this may be taken as the lower limit. The proteins also remain practically constant at

3·4% irrespective of the amount of solids-not-fat, whilst the lactose varies from 4·9—4·0%.

Calculation of added water and fat abstracted.

When the solids-not-fat are less than 8·5%, the deficiency is found by subtracting the amount of solids-not-fat from 8·5, multiplying by 100 and dividing by 8·5.

Where the various constituents are in the ratio given by normal milk, the % deficiency of solids-not-fat may be taken as added water.

When the % fat is less than 3·0 it may be presumed that the milk has been adulterated by the abstraction of fat, or by the addition of separated milk. The % deficiency of fat is calculated by subtracting the % fat found from 3·0, multiplying by 100 and dividing by 3.

Routine Examination of Milk.

For the routine examination of milk, it is usually only necessary to determine the specific gravity and the fat by the Gerber or Babcock method, the solids-not-fat being found by calculation. In case the Gerber or Babcock method is not used, the total solids may be estimated and the specific gravity observed.

For the determination of total solids, flat porcelain dishes, seven centimetres in diameter, may be used. These will keep their weight practically unchanged for a considerable time. The milk is delivered from the pipette described under the determination of the fat by the Adam's method. Neither the dish nor the milk need be weighed, as the weight of the former will be known and that of the latter will be approximately five grams. The milk is dried as usual and weighed, when the weight of solids, multiplied by twenty, will give the percentage of Total Solids.

Boric acid and formaldehyde should be tested for. If the Gerber or Babcock process is used, the detection of the latter should be carried out at the same time as previously indicated.

Examination and Analysis of Sterilized Milk.

This may be examined in the same manner as ordinary milk, the only points of difference being : (a) the milk sugar, protein, ash ratio is not applicable, as the bulk of the albumin is removed during the treatment, thereby reducing the protein content by 0·3—0·4%, and (b) the milk is usually " homogenized " before sterilization, *i.e.*, the milk is forced through fine holes under pressure, which breaks up the fat globules, reducing them to a very small size, and under these conditions they no longer coalesce and the cream does not rise. Whichever method is used for estimation of fat, the extraction must be much more thorough than is necessary for ordinary milk.

Examination and Analysis of Condensed Milk.

Condensed milk is manufactured by concentrating milk under reduced pressure with or without the addition of cane sugar and packing the product in sealed tins. The various brands used at the present time are as follows :—

	Fat.	Solids-not-fat.	Sucrose.
Evaporated milk - - - -	7— 8%	16—17%	—
Unsweetened condensed milk	9—12%	23—25%	—
Sweetened full-cream milk -	9—10·5%	23·5—27%	38—42%
Sweetened machine-skimmed milk - - - - - - -	0·5— 1%	25—29%	44—47%

For analysis about 30 grm. of the milk is diluted with water, boiled, cooled, made up to 100 cc., then treated as an ordinary milk. In the case of sweetened milk which has crystallised, the contents of the tin should be dissolved in a suitable amount of water, taking care that all the milk sugar redissolves.

Total solids. In the case of unsweetened milk the estimation is carried out on the dilute solution, as in the case of milk. If the sample is sweetened, the most satisfactory method is to weigh a dish containing about 20 grm. of clean, dry white sand, and pipette 5 cc. of the solution on it, distributing evenly over the sand, and dry to constant weight. Alternatively, 2·5 cc. of the solution may be weighed into a deep metal dish, diluted with 50 cc. of water and evaporated slowly to dryness on the water-bath, and finally dried to constant weight in the water-oven.

Fat. The Röse-Gottlieb method is the only completely satisfactory one. The Adams' method gives too low or too high a result according to whether the ether is anhydrous or contains a small amount of water.

Determination of proteins and ash.

These may be determined by the processes as given under " Milk."

Sugars. A method for the polarimetric determination of lactose and sucrose is described by Harrison (*Analyst*, 1904, **29**, 248; *cf.* Revis and Payne, *Ibid.*, 1914, **39**, 476).

Milk sugar may be estimated by the Fehling process, as given under " Milk," and cane sugar calculated by difference, or the following method may be used : 10 cc. of the milk solution are placed in a 100 cc. flask, diluted to about 50 cc., and neutralised with N/10 NaOH. Copper sulphate solution (Fehling solution A) is added drop by drop until the flocculent precipitate settles to leave a clear solution. The volume is made up to 100·67 cc. and the liquid is mixed and filtered (*a*).

25 cc. of the filtrate are placed in a flask, 25 cc. of water and 5 cc. of concentrated hydrochloric acid added, and the

flask is placed in a water-bath at 70°C. for 10 mins., cooled and the solution filtered and made up to 100 cc. (b).

Lactose is determined in filtrate (a) by the gravimetric Fehling method, and total sugar in solution (b). If the CuO due to lactose be subtracted from the total CuO from solution (b), the cane sugar may be calculated from the difference.

The Public Health (Condensed Milk) Regulations, 1923, require condensed milk to be labelled in a manner which is set out in the schedule of the regulations. They also require that all condensed milk shall contain not less than an appropriate percentage of milk fat and milk solids as specified in the following table :—

Description of Condensed Milk.	Percentage of milk and fat.	Percentage of all milk solids, including fat.
1. Full cream, unsweetened ...	9·0	31·0
2. Full cream, sweetened ...	9·0	31·0
3. Skimmed, unsweetened ...	—	20·0
4. Skimmed, sweetened ...	—	26·0

Examination and Analysis of Dried Milk.

Dried milk is manufactured as full-cream milk, half-cream milk and machine-skimmed milk. In any case a 12—14% solution should be made and treated as ordinary milk. In case the milk does not completely dissolve in water, the powder may be directly worked on 0·5—1 grm. diluted to 5 cc. with water for the Röse-Gottlieb method; 2 grm. for moisture and ash; 2 grm. for proteins; and 1 grm. extracted with boiling water and made up to 100 cc. for sugar.

Examination and Analysis of Cream.

Determination of total solids and ash.

For total solids about 2 grm. are used, proceeding as under " Milk."

For ash, at least 5 grm. should be used.

Determination of fat.

The Röse-Gottlieb method. 1 grm. is weighed into the tube, and diluted with water to 5 cc., proceeding as under " Milk."

The Gerber method. 10 cc. of water, 10 cc. of Gerber sulphuric acid and 1 cc. of amyl alcohol are placed in one of the special Gerber cream tubes. 5 grm. of cream are weighed out into the small tube attached to the stopper, and the whole added to the tube by quickly inserting and adjusting the stopper. The whole is well shaken, the small stopper being loosened. It is heated up to 70°C. in a bath, whirled for about 3 mins. in the centrifuge, again heated to 70°C., and the percentage of fat read off on the tube.

In calibrating the Gerber tubes it should be noted that 60% of fat in the tube occupies 3·34 cc.

Preservatives.

Boric acid is tested for, as under " Milk." The amount of boric acid may be determined by weighing out about 20 grm., and proceeding as under " Milk "

Benzoic acid may be tested for, and if necessary determined by the methods given under milk.

Formaldehyde may be detected and determined as given under " Milk," after diluting with milk of known purity.

Detection of thickening agents.

Starch may be detected by means of iodine.

Gelatin may be detected by means of Stokes' reagent (prepared by dissolving mercury in twice its weight of nitric acid of Sp. Gr. 1·42, and diluting with water to 25 times its volume) in the following manner : 10 cc. of the cream, 20 cc. of water and 20 cc. of the reagent are mixed together, shaken vigorously, allowed to stand for 5 mins. and filtered ; in presence of much gelatin, it will be impossible to obtain a clear filtrate, whilst the addition of an equal volume of a saturated aqueous picric acid solution to the filtrate will produce immediately a yellow precipitate.

Calcium saccharate (" Viscogen ") may be detected by estimating the percentage of lime in the ash, which on the average is 22·4% (*Analyst*, 1908, **33**, 401).

Cane sugar may be detected as follows : 15 cc. of milk or cream are mixed with 1 grm. of resorcinol and 1 cc. of strong hydrochloric acid, and the mixture raised to the boil. Cane sugar produces a red colour; a milk of known purity should be similarly treated for comparison. (Cf. *Analyst*, 1918, **43**, 292.)

Legal requirements.

According to the Milk and Cream Regulations of 1912 and the amendment of 1917, no addition of any kind must be made to cream containing less than 35% of fat. The only permissible preservatives which may be added to cream containing more than 35% of fat are boric acid, borax, or hydrogen peroxide, the percentage of the two former being not greater than 0·4%, calculated as boric acid, providing that a label of stated dimensions is attached to the receptacle containing the preserved cream.

Examination and Analysis of Butter.

In the ordinary examination of butter, the two chief points are the nature of the fat and the amount of water present. Other determinations often required are the amount of milk solids, of salt and of preservatives.

Determination of water, casein and salt.   2 grm. are

heated in a flat-bottomed dish for 2 hrs. on the water-bath or 10 grm. are heated in a basin over a small flame (with care to prevent burning) until all evolution of bubbles has ceased. Casein and salt may be determined by washing the residue with ether until free from fat, drying and weighing; the casein settles very rapidly, and the ether can be decanted without loss. Salt is determined by dissolving the residue in water and titrating with $N/10$ silver nitrate, or by taking the ash of the butter (obtained at a low temperature) as salt.

Dried milk is occasionally added to butter, and may be detected by determination of the milk sugar, which does not exceed 0.4% in a normal butter.

The percentage of fat may be determined by evaporating the ether and weighing the fat, but it is usually quite satisfactory to determine fat by difference.

Water may be determined in routine work by means of the Stokes' tube (*Richmond*, 3rd edition, p. 240). This tube is a cylindrical one open at both ends, the upper half having a diameter of 28 mm., and the lower half having a diameter of 9 mm. The lower half is closed by a rubber bung, and is calibrated into divisions each one representing 1% of water in the butter. The tube, with the bung in position, is immersed in hot water, and butter is added up to a 15 cc. mark on the upper half. The tube is then transferred to a centrifuge and is whirled until all the water has collected in the narrow end of the tube. The approximate percentage of water can then be read off directly. The clarified butter fat which is perfectly clear and practically dry may be removed and used for the other determinations.

According to the Sale of Butter Regulations, 1902, " where the proportion of water in a sample of butter exceeds 16%, it shall be presumed for the purposes of the Sale of Food and Drugs Act, 1875—1899, until the contrary is proved, that the butter is not genuine by reason of the excessive amount of water therein."

Examination of fat. About 20 grm. of butter are melted in a small beaker on the water-bath. The appearance of the melted fat should be carefully noticed. In the case of a pure untreated butter the water and curd will sink to the bottom, and the fat will be quite clear. In the case of margarine, the fat will always be turbid, although turbid fat does not necessarily imply adulteration, some reworked butters often showing a certain amount of turbidity. The fat is filtered through a thick filter paper into another beaker, and is then used for further examination.

The chief method of examination is the Leffmann-Beam modification of the Reichert-Wollny process with the later modifications of Polenske and Kirschner.

Reichert-Polenske process. 5 grm. of the fat are weighed out into a 300 cc. flat-bottomed flask, 20 grm. of glycerol and 2 cc. of 50% caustic soda solution are added, and the flask is heated until the contents are clear. (In case a number of samples have to be examined, it is convenient to prepare a quantity of glycerol containing the requisite amount of soda and to measure out about 20 cc. of this " glycerol soda " for each experiment.) 100 cc. of boiled distilled water are added, and the soap is dissolved. 0·1 grm. of pumice, which has been ground and sifted through muslin, is added, and 40 cc. of sulphuric acid (of such concentration that 35 cc. neutralise 2 cc. of the caustic soda solution) are added. The flask is then connected with the distilling apparatus, which is of standard proportions (*Analyst*, 1904, **29**, 154). This apparatus, is somewhat similar to the Reichert-Wollny apparatus, but the condenser is upright. The flask is heated gently until the acids melt, and then the flame is adjusted so that 110 cc. distil in 19 to 21 mins. The flask containing the distillate is removed and replaced by a 25 cc. cylinder to catch any drops. The contents of the 110 cc. flask are mixed and cooled. The distillate is then filtered, and 100 cc. are titrated with N/10 soda. The number of cc.'s of N/10 soda used (less that used in the blank experiment), multiplied by 1·1 (to correct for the 110 cc.'s distilled), gives the Reichert-Wollny number. The condenser tube, flask and cylinder are washed with 18 cc. of water, and the washings poured through the filter; the condenser, flask, and cylinder are then washed with 20, 15, and 10 cc. of alcohol respectively, pouring the washings through the filter. The mixed alcoholic solutions are then titrated with N/10 caustic soda, using phenolphthalein as indicator, and a blank experiment is also carried out. The number of cc. of N/10 caustic soda less the blank is the Polenske value.

The Polenske number generally varies with the Reichert-Wollny number. For butters with a Reichert-Wollny number of 20, the Polenske number is about 1·3; when the Reichert-Wollny number is 25, the Polenske number is about 1·8; and when the Reichert-Wollny number is 30, the Polenske number increases to 2·5 to 3·0.

The Butter Regulations Committee recommended that a Reichert-Wollny number of 24 be taken as the limit for butter, and a Reichert-Wollny number of 4 as representing 10% of butter fat when margarine is under examination. The presence of coconut oil, however, which has come largely into use since this recommendation was made, renders these figures useless unless the absence of coconut oil or similar products is proved. An average Reichert-Wollny number for genuine butter is about 28 to 32. A lower Reichert-Wollny

number value than 24, together with a low Polenske number, would suggest the presence of oleo-margarine (Reichert number about 1), whilst a higher Polenske number than that corresponding to the Reichert number would indicate the presence of coconut oil or other similar substance.

Kirschner process. 0·5 grm. of finely-powdered silver sulphate is added to the 100 cc. of the neutralised distillate of volatile fatty acids obtained in the Polenske process, and after standing for an hour with occasional shaking the liquid is filtered. 100 cc. of the filtrate are placed in the distilling flask, 35 cc. of water, which has been well boiled, and 10 cc. of the sulphuric acid solution previously used, added; a small amount of pumice is placed in the flask, and 110 cc. distilled as in the Polenske process; 100 cc. of the distillate are titrated with N/10 caustic soda, and after correction for the figure obtained in a blank experiment, the Kirschner number is calculated by multiplying the number of cc. of N/10 alkali by 1·21 and by $(100 + X) \div 100$ (X = cc. of alkali added to the Reichert distillate for neutralisation). The Kirschner process is of special value for estimation of the quantity of butter in mixtures containing small amounts when large quantities of other fats are present, *e.g.*, in margarine, which under the Margarine Act is not permitted to contain more than 10% of butter.

Calculation of the percentage of Butter, Coconut Oil and Oleo-margarine in Mixtures.

The following method of calculation has been worked out by Cribb and Richards (*Analyst*, 1911, **36**, 327) and by Arnaud and Hawley (*Analyst*, 1912, **37**, 122) :—

R = Reichert number, P = Polenske number, K = Kirschner number.

The figures for oleo-margarine may be taken as $R = 0·3$, $P = 0·4$, $K = 0·3$.

T = Transfer number which is 1·9, unless P is less than 2·5, in which case T is found from the curve given by Arnaud and Hawley

Polenske number due to coconut oil = $P - 0·4 + T - R/10$.

$$\% \text{ Coconut oil in sample} = \frac{\text{Polenske no. due to coconut oil}}{0·176}$$

(P for coconut oil = 17·6).

Reichert number due to butter

= $R - 0·3 - T - (0·065 \times \text{percentage of coconut oil})$.

$$\% \text{ Butter fat} = \frac{\text{Reichert due to butter}}{0·29}$$ (this assumes R for butter = 29·0)

(N.B.—The factor $0·065 \times \%$ coconut oil gives the Reichert due to coconut oil and assumes that for coconut oil $R = 6·5$.)

To calculate from Kirschner (K).

Kirschner number due to butter.
$$= K - 0.3 - P/10.$$

$$\% \text{ Butter} = \frac{\text{Kirschner no. due to butter}}{0.23} \quad (K \text{ for butter} = 23).$$

This is the most reliable method of estimating up to 25% of butter in margarine.

Oleo-margarine $= 100 - \%$ coconut oil $- \%$ butter.

For a detailed discussion of these methods of calculation, see Elsdon and Smith (*Analyst*, 1925, **50**, 53).

The above method of calculation assumes that the oil present having a high Polenske number is coconut oil. Recently large quantities of palm kernel oil have been used in the manufacture of margarine, the presence of which considerably complicates the calculation. Methods for distinguishing between these two oils have been proposed by Burnett and Revis (*Analyst*, 1913, **38**, 255), and by Elsdon, (*Analyst*, 1917, **42**, 72, 295, 298).

An alternative method for the determination of coconut oil and similar products in mixtures has been suggested by Shrewsbury and Knapp (*Analyst*, 1910, **35**, 385). For this method and for various comments and modifications the original paper should be consulted together with the following references: *Analyst*, 1911, **36**, 195, 327, 344; 1912, **37**, 3; 1917, **42**, 72. This method has been combined with the Reichert-Polenske process by Elsdon (*Ibid.*, 1917, **42**, 295).

A process somewhat similar to that of Polenske has been proposed by Blichfeldt (*J.S.C.I.*, 1910, **29**, 792; 1919, **38**, 1501), which is largely used by margarine manufacturers in England. A modification of this is due to Gilmour (*Analyst*, 1920, **45**, 2), but neither process would seem to have any particular advantage over that of Polenske

Refractometer.

A rapid method of examination is by means of the refractive index. This may be found either by means of the Abbé refractometer or the Zeiss butyro-refractometer. The former reads directly in refractive indices; the latter on an arbitrary scale, divided into a hundred parts. Pure butter has a refractive index of about 1.454, oleo-margarine 1.459, whilst coconut oil is usually less than 1.450. A suitable mixture of coconut oil and oleo-margarine will therefore have the same refractive index as pure butter.

Preservatives.

The Departmental Committee on the Use of Preservatives in Food recommended that the only preservative permitted to be used in butter and margarine be boric acid, or mixtures

of boric acid and borax, in proportions not exceeding 0·5% calculated as boric acid.

Detection of boric acid. A few drops of the water which has settled from the melted butter are placed in one of the depressions of a spot-plate. 1 drop of tincture of turmeric, and one drop of hydrochloric acid (for concentrations see under "Milk") are added; on drying on the water-bath, a red coloration will be produced in the presence of boric acid.

Determination of boric acid. 6·2 grm. of butter are weighed out into a 250 cc. wide-mouthed flask. About 50 cc. of water are added and a few drops of litmus solution. The whole is then made acid with a few drops of N/10 hydrochloric acid, and boiled for a few minutes to eliminate carbon dioxide. The solution is cooled, neutralised to litmus with N/10 caustic soda, about 20 cc. of glycerol or 10 grm. mannitol added and the titration continued until neutral to phenolphthalein. Each cc. of soda used (allowing for any acidity due to the glycerol) after the addition of the glycerol, is equivalent to 0·1% of boric acid in the butter. In an alternative method two or three times the amount of butter may be melted in a separator, washed out several times with hot water, the washings mixed, made up to a known volume and an aliquot portion evaporated to dryness with a slight excess of caustic soda and ignited; the boric acid in the residue is then determined as before.

Other preservatives occasionally found in butter are salicylic acid and fluorides. Salicylic acid may be detected as under "Milk." Fluorides may be detected in the following manner : "10 grm. of the sample are melted and shaken up in a separator and heated with 1—2 cc. of water. The aqueous layer is run off into a test-tube, a few drops of hydrogen peroxide and 1 cc. of a solution containing about 2% titanium sulphate in 10% sulphuric acid added. A blank test is made in exactly the same way on 10 grm. of pure butter. If the original sample contains fluoride, the orange yellow colour of the peroxidised titanium solution will be partially discharged, and on comparison with the colour obtained in the blank test on pure butter the difference is seen to be very marked." (L.G.B. Food Reports, No. 17).

Routine Examination.

15 cc. of the sample are placed in one of the Stokes' butter tubes already mentioned. The tube is heated to 70° in the water-bath, whirled for 3 mins. in a centrifuge, and the amount of water is noted. The fat, which is sufficiently clear for subsequent examinations, is then decanted, and the tube filled up to the mark with approximately N/5 hydrochloric acid. The curd is broken down by means of a glass rod, and the

liquid thoroughly mixed. 10 cc. of this liquid are removed by means of a pipette to a 50 cc. beaker and mixed with 5 cc. of turmeric tincture (prepared by warming 5 grm. of powdered turmeric and 5 grm. of crystallised tartaric acid with 500 cc of industrial methylated spirit for 4 hrs. and filtering), allowed to stand for 1 hr. and compared with a similar solution prepared with a butter known to be free from boric acid. If the yellow colour produced by the sample is deeper than that produced by the butter of known purity, standards should be prepared representing 0·5%, 0·3% and 0·1% boric acid by taking 5 cc., 3 cc. and 1 cc. of a standard boric acid solution (prepared by dissolving 1% of boric acid in approximately $N/5$ hydrochloric acid), making up to 9·5 cc. with $N/10$ hydrochloric acid, and adding 0·5 cc. of milk; the colours are compared at the end of 1 hr. (Hawley, *Analyst*, 1915, **40**, 150). The separated fat may be examined by the Reichert process.

Examination and Analysis of Cheese.

Determination of water and ash. This may be carried out by drying 5 grm. of the sample, cut into very thin slices, at 105°C. until constant in weight; the addition of a small amount of absolute alcohol will assist the drying. The ash may be determined on the same portion, heating gently to not more than a dull red in the dark. Gorgonzola cheese is frequently coated with a fairly thick layer of a mixture of tallow and barytes. The amount of coating in extreme cases being as much as one-third of the weight of the whole cheese.

Determination of chlorides. 1 grm. of cheese is placed in a Kjeldahl flask with 20 cc. of strong sulphuric acid. A nitrogen bulb containing a known volume of $N/10$ silver nitrate and some strong nitric acid is inserted into the neck of the flask by means of a tightly-fitting cork. The flask is clamped in an almost horizontal position and heated. When the reaction is complete the residual silver nitrate is determined, and from this the amount of chloride calculated.

Determination of proteins. This is carried out by the Kjeldahl process, using about 1·5—2 grm. of cheese. The percentage of nitrogen multiplied by 6·38 is equal to the percentage of proteins.

Determination of Fat.
Gerber method. This is carried out exactly as described under " Cream," with the exception that the 5 grm. of cheese are added directly to the Gerber tube and not weighed out in the small tube. In the case of certain cheeses a considerable time is required for complete disintegration.

Extraction method. 1—2 grm. are ground up to a fine powder with at least an equal quantity of sand, and the mixture transferred to a stoppered cylinder and extracted several times with ether. The ethereal solution is evaporated and the fat dried and weighed. The Röse-Gottlieb method may also be used with advantage.

Examination of fat. A quantity of cheese is cut up into fairly small pieces and placed on a porcelain filter plate resting in a funnel, and allowed to remain in the water-oven until the fat has run off. If sufficient fat cannot be obtained by this method, extraction with ether and evaporation must be resorted to. The fat so obtained is examined by the methods given under "Butter-fat."

The composition of various kinds of cheese is treated by the following among others : Camembert cheese (Buttenburg and Guth. *Analyst*, 1908, **33**, 5) ; cream cheese (Cribb. *Ibid.*, 1909, **34**, 45) ; Dutch cheese (Cribb. *Ibid.*, 1906, **31**, 105 ; Van Rijn. *Ibid.*, 1915, **40**, 391) ; Roquefort cheese (Dox. *Ibid.*, 1911, **36**, 542).

STANDARD UNITED STATES METHODS.

In case the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists differ from the standard English methods, a summary of the differences is given below.

Examination and Analysis of Milk.

Determination of fat.

Röse-Gottlieb method.

10—11 grm. of the milk is thoroughly mixed with 1·25 cc. of concentrated ammonium hydroxide (2 cc. if the sample is sour) in a Rohrig tube or similar apparatus, and then with 10 cc. of alcohol (95% by vol.). The mixture is shaken for 30 secs. with 25 cc. of washed ether, then shaken again for 30 secs. after addition of 25 cc. of petroleum ether (B.Pt. below 60°C.). After allowing to stand for 20 mins., the ethereal solution of fat is drawn off as completely as possible, and filtered into a tared flask. The liquid remaining in the tube is re-extracted with 15 cc. of each ether, shaken for 30 secs., and the clear solution drawn off and filtered, through the same filter, into the same tared flask. The tip of the spigot of the extraction tube, the funnel and the filter, are washed with a mixture of equal parts of the two ethers, and then the united ethereal

Analyses of Milk of Known Purity. (Lythgoe).

Breed.	Weight of Milk (lbs.).	Sp. Gr. 15°C. (Quevenne Scale).	Total Solids.	Fat.	Lactose.	Protein.	Ash.	Solids-not-fat.
Grade Durham ..	15	35	14.58	5.10	5.00	3.35	0.81	9.48
Holstein	15	34	13.65	4.50	4.95	3.33	0.72	9.15
Grade	20	33	13.36	4.30	5.00	3.25	0.81	9.06
Grade Ayrshire ..	12	33	13.26	4.20	5.50	2.84	0.66	9.06
Grade Swiss	16	33	13.20	4.35	4.75	3.29	0.76	8.85
Grade Durham	15	33	13.06	3.80	5.75	3.37	0.69	9.26
Ayrshire	10	31	12.91	3.90	4.35	3.51	0.76	9.01
Grade Holstein	17	32	12.78	4.00	5.05	2.89	0.71	8.78
Holstein	10	31	12.66	3.90	4.35	2.97	0.76	8.76
Grade Durham	18	34	12.54	3.50	5.25	2.97	0.68	9.04
Grade Ayrshire ..	16	32	12.08	3.70	4.65	2.80	0.78	8.38
Grade Holstein	20	34	12.00	3.10	5.05	2.99	0.71	8.90
Holstein	16	33	11.40	3.20	5.00	2.48	0.72	8.20
Holstein	28	30	10.20	2.65	4.50	2.40	0.65	7.55

Quevenne Lactometer Degrees. The lactometer reading is expressed in whole numbers for convenience; the true Sp. Gr. is obtained by writing 1.0 before the lactometer reading. To convert Quevenne degrees to New York Board of Health degrees, they must be divided by 0.29.

filtrates and washings are evaporated slowly and dried in a boiling water-oven to constant weight. For accurate results, a third extraction is advisable. The fat is re-dissolved in petroleum ether, and if any residue remains, it is filtered off, dried, and the weight deducted from the original weight.

Babcock method.

This test is performed in special Babcock bottles, with long, narrow, graduated necks; the graduations, in the case of milk bottles cover 8%, divided in 1/10ths%, and in the case of cream bottles cover 50%, graduated in halves of 1%. 17·6 cc. of the milk are run from a pipette (graduated to deliver 17·6 cc. of water at 20°C. in 5 to 8 secs.) into the bottle, together with 17·5 cc. sulphuric acid (Sp. Gr. 1·82—1·83). The milk and acid are well mixed, and when the curd is dissolved, are centrifuged for 4 mins. at the required speed for the centrifuge employed. Boiling water is added to bring the fat within the scale on the neck of the bottle, and after a further centrifuging of 1 min., the percentage of fat is read directly from the length of the column of fat, readings being made at 57—60°C., at which temperature the fat is wholly liquid.

For details of the manipulation of the Babcock test, and its application in the analysis of dairy products other than milk, see Farrington and Woll, " Testing Milk and Its Products," and Van Slyke, " Modern Methods of Testing Milk."

Calculation of added water and fat abstracted.

This calculation is made as under English methods for milk, except that the particular State and municipal standard should be substituted if it differs from 8·5% of solids-not-fat and 3·0% of fat.

Adulteration of milk.

Until recently the standard for milk was not less than 8·5% of solids-not-fat, and not less than 3·25% of fat, but this national standard is not now in force, and adulteration is controlled by the State and Municipal standards which range from 11 to 13% as minimum limits for total solids, and from 2·5 to 3·7% as minimum limits for fat.

Examination and Analysis of Cream.

Determination of fat.

The Babcock method. 9 or 18 grm. of cream is weighed into a tared Babcock bottle, and made up to 18 grm. with water if necessary. 17·5 cc. of sulphuric acid is added, and the process continued as under " Milk " (see above).

Examination and Analysis of Butter.

U.S. standard butter is butter containing not less than 82·5% of butter fat. By Acts of Congress, approved August 2 1886 and May 9 1902, butter may also contain added colouring matter, but the colour added must conform to the general regulations governing use of colouring in food products.

Preservatives.

Formerly " boric mixture " (borax and boric acid) was used in the United States, and its use is still permitted in England. Now, only sodium benzoate may be used in the United States, and that must be declared. Dairymen seldom use it in butter for domestic use, but some brands of nut butter contain it. Formaldehyde, salicylic acid and sulphurous acid are more infrequently used in butter as preservatives.

Detection and determination of benzoic acid.

The aqueous portion is separated from 10 grm. of butter, and the fat shaken several times with hot sodium bicarbonate solution. The mixed washings and aqueous portion are heated with an equal volume of concentrated hydrochloric acid, and the method continued as under milk (see earlier).

An alternative method of detection (official method of the A.O.A.C.) is the *Halphen-Robin method*. 25 grm. of the melted sample is agitated with a solution of 0·4— 0·5 grm. of sodium bicarbonate in 50 cc. of water and 15 cc. of 95% alcohol in a separating funnel. After allowing to stand 6 mins., the alkaline liquor is drawn off into a flask, and acidified with concentrated sulphuric or hydrochloric acid. The contents of the flask are then heated almost to the boil, shaken with a small amount of talc or infusorial earth, and filtered, returning the first portions through the filter until the filtrate runs perfectly clear. The filtrate is cooled, extracted with 40 cc. of ether, the ether extract washed with a mixture of 20 cc. of water and 5 cc. of 95% alcohol, and tested by the *Mohler* method as follows :

The ether extract is evaporated to dryness, the residue dissolved up in 1 to 3 cc. of $N/3$ sodium hydroxide, and again evaporated to dryness. To the residue are added 5—10 drops of concentrated sulphuric acid and a crystal of potassium nitrate. The mixture is heated for 20 mins. in a boiling water bath, forming meta-di-nitro benzoic acid. After cooling, the mixture is diluted with 1 cc. of water, made distinctly ammoniacal, and boiled to decompose any ammonium nitrite formed. The solution is cooled and a few drops of colourless ammonium sulphide solution run down the side of the tube.

A red-brown ring (ammonium meta-di-amido benzoic acid) at the junction of the two layers indicates the presence of benzoic acid. On mixing and heating, the colour changes to greenish-yellow (distinction from salicylic and cinnamic acids). The presence of phenolphthalein interferes with the test.

Examination and Analysis of Cheese.

Determination of acidity. Water at 40°C. is added to 10 grm. of the finely divided cheese until the total volume is 105 cc. The mixture is shaken thoroughly, filtered, and 25 cc. of the filtrate (representing 2·5 grm. of the sample) is titrated with N/10 sodium hydroxide. The result is expressed as percentage of lactic acid.

U.S. standard cheese contains at least 50% of fat.

Examination and Analysis of Ice Cream.

The sample is allowed to soften at room temperature, and thoroughly mixed by means of a spoon or egg-beater, or by pouring back and forth between beakers.

Determination of fat. 4 grm. of the sample is thoroughly mixed with 3 cc. of water in a small dry beaker, transferred to a Rohrig tube, washing out the beaker with an additional **3 cc.** of water. 2 cc. of concentrated ammonium hydroxide are added, and the whole well mixed and heated in a water-bath at 60°C. From this point, the procedure is as under the Röse-Gottlieb method (See " Milk Analysis.").

The *U.S. standard* for ice cream is not less than 14% of milk fat, except when mixed with fruit or nuts, when the standard is 12%.

Detection of thickening ingredients. See under " cream."

Artificial Colouring Matters in Dairy and other Food Products.

The laws of the United States (more particularly the Food and Drugs Act, 1906) do not prohibit the addition of artificial colouring substances to food, unless (*a*) the colouring matter added is poisonous, or otherwise objectionable, and (*b*) the colouring matters serve to conceal damage or inferiority). However, in most States the laws have the practical effect of excluding artificial colouring from most food products on one or other of the above grounds. The detection and identification of artificial colours is a complicated procedure, for complete instructions regarding which see (*a*) " Methods of

Analysis: Association of Official Agricultural Chemists," Washington, D.C., and (*b*) "Food Inspection and Analysis," by A. E. Leech, 4th ed.

Seven coal tar dyes have been definitely approved by the U.S. Department of Agriculture, and are usually referred to as the seven certified colours.

The following quotation from "Food Inspection Decision," No. 76, July 13th, 1907, explains the conditions under which these can be used :—

"The use of any dye, harmless or otherwise, to colour or stain a food in a manner whereby damage or inferiority is concealed is specifically prohibited by law. The use in food for any purpose of any mineral dye or any coal-tar dye, except those coal-tar dyes hereinafter named, made specifically for use in foods, and which bear a guarantee from the manufacturer that they are free from subsidiary products and represent the actual substance, the name of which they bear, may be used in foods. In every case a certificate that the dye in question has been tested by competent experts and found to be free from harmful constituents must be filed with the Secretary of Agriculture and approved by him. The following coal-tar dyes which may be used in this manner are given numbers, the numbers preceding the names referring to the number of the dye in question as listed in A. G. Green's edition of the 'Schultz-Julius Systematic Survey of the Organic Colouring Matters,' published in 1904. The list is as follows :

Red shades : 107 Amaranth. 56 Ponceau 3 R. 517 Erythrosin.
Orange shade : 85 Orange I.
Yellow shade : 4 Naphthol yellow S.
Green shade : 435 Light green S. F. yellowish.
Blue shade : 692 Indigo disulpho acid.

Each of these colours shall be free from any colouring matter other than the one specified, and shall not contain any contamination due to imperfect or incomplete manufacture."

CARBOHYDRATES.

F. Robinson, M.Sc. Tech., B.Sc., F.I.C.

BEHAVIOUR OF SUGARS TOWARDS CERTAIN REAGENTS.

Sugar.	Fehling's solution.	Knapp's solution.	Sachsse's solution.	Barfoed's solution.	Nylander's solution.
Dextrose	ppt.	ppt.	ppt.	ppt.	ppt.
Lævulose	ppt.	ppt.	ppt.	ppt.	ppt.
Invert sugar	ppt.	ppt.	ppt.	ppt	ppt.
Galactose	ppt.	ppt.	ppt.	ppt.	ppt.
Lactose	ppt.	ppt.	ppt.	–	–
Maltose	ppt.	ppt.	ppt.	–	–
Sucrose	–	–	–	–	–

The above tests are to be carried out at the boil.

Fehling's solution.

(A) Copper solution.

69·2 grm. recrystallised $CuSO_4.5H_2O$, made up to 1000 cc.

(B) Alkaline tartrate solution.

346 grm. Rochelle salt and 130 grm. caustic soda made up to 1000 cc.

The two solutions are to be kept separate, and equal volumes mixed as required, from which mixture the volumes required are measured.

As Fehling's solution usually gives a few mgm. Cu_2O when heated to 100°C., a blank to determine this amount should be made with each fresh solution and the necessary correction made in all sugar estimations.

Knapp's solution. 10 grm. mercuric cyanide in 100 cc. NaOH solution (1·145 Sp. Gr.), made up to 1000 cc.

Sachsse's solution. 18 grm. mercuric iodide, 25 grm. potassium iodide, and 80 grm. KOH in 1000 cc.

Barfoed's solution. 66 grm. cupric acetate and 10 cc. glacial acetic acid are dissolved in water and diluted to 1000 cc.

Nylander's solution. 40 grm. Rochelle salt and 20 grm. bismuth subnitrate dissolved in 1000 cc. of 8 per cent. caustic soda solution.

I. Cane Sugar.

I. Determination of Invert Sugar in Commercial Cane Sugars.

In case the invert sugar is under 3 per cent., Method A may be used; for all cases in which the invert sugar is over 2·5 per cent., Method B may be used.

Method A.

	Per cent. Invert.
Herzfeld's method determines between	0·05 and 1·50
Baumann's „ „ „	0·04 and 3·21

3·33 grm. of a sample containing more than 1·5 per cent. invert sugar completely reduces 10 cc. Fehling's solution, and Baumann's method must then be used.

Herzfeld's method. For fairly pure products 20 grm. are dissolved up to 100 cc. and 50 cc of the filtrate taken.

In other cases 25 grm. are dissolved up to 100 cc. after adding basic lead acetate; 60 cc. of the filtrate are treated with sodium carbonate solution to remove lead, made up to 75 cc., and 50 cc. of the filtrate taken (= 10 grm. original substance).

The 50 cc. filtrate is mixed with 50 cc. Fehling's solution in an Erlenmeyer flask, and raised to the boil in 3–4 minutes over a wire gauze circle in an asbestos board, and boiled for exactly 2 minutes; 100 cc. of water are added and the liquid filtered through asbestos in a tared Gooch crucible. The asbestos used in preparing the filter must be boiled previously with caustic soda solution. The filter is not allowed to run dry, and the precipitated Cu_2O is washed on with cold water; finally, the filter is washed with hot water, alcohol, and ether, dried, ignited inside another crucible to CuO, and weighed. It is preferable to weigh as CuO, since any impurities carried down with the Cu_2O are thereby burnt away.

$$CuO \times 0·79892 \; (Log. = 1·90205) = Cu$$

B 2

PER CENT. INVERT SUGAR IN CANE SUGARS (Herzfeld).

Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.
50	0.05	120	0.40	190	0.79	260	1.19
55	0.07	125	0.43	195	0.82	265	1.21
60	0.09	130	0.45	200	0.85	270	1.24
65	0.11	135	0.48	205	0.88	275	1.27
70	0.14	140	0.51	210	0.90	280	1.30
75	0.16	145	0.53	215	0.93	285	1.33
80	0.19	150	0.56	220	0.96	290	1.36
85	0.21	155	0.59	225	0.99	295	1.38
90	0.24	160	0.62	230	1.02	300	1.41
95	0.27	165	0.65	235	1.05	305	1.44
100	0.30	170	0.68	240	1.07	310	1.47
105	0.32	175	0.71	245	1.10	315	1.50
110	0.35	180	0.74	250	1.13		
115	0.38	185	0.76	255	1.16		

Baumann's method. Many products, especially syrups and molasses, give green copper compounds if 10 grm. of substance is used, thereby interfering with the invert sugar estimation; therefore in such cases only 10 grm. is dissolved up to 100 cc. and 50 cc. taken and treated as in the Herzfeld method.

PER CENT. INVERT SUGAR IN CANE SUGARS (Baumann).

Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.	Cu. mgm.	Invert per cent.
35	0.04	110	0.83	185	1.65	260	2.50
40	0.09	115	0.88	190	1.70	265	2.56
45	0.14	120	0.93	195	1.76	270	2.62
50	0.19	125	0.99	200	1.82	275	2.68
55	0.25	130	1.04	205	1.87	280	2.74
60	0.30	135	1.10	210	1.93	285	2.79
65	0.35	140	1.15	215	1.98	290	2.85
70	0.40	145	1.21	220	2.04	295	2.91
75	0.45	150	1.26	225	2.10	300	2.97
80	0.51	155	1.31	230	2.16	305	3.03
85	0.56	160	1.37	235	2.21	310	3.09
90	0.61	165	1.42	240	2.27	315	3.15
95	0.66	170	1.48	245	2.33	320	3.21
100	0.72	175	1.54	250	2.39		
105	0.77	180	1.59	255	2.44		

Method B. H. Brown, Morris and Millar, *J.C.S.*, 1897, **71**, 278.
The actual Cu weighed should be between 0·15 and 0·35 grm.
$$(= 0·07\text{–}0·17 \text{ grm. dextrose}).$$

The actual CuO weighed should be between 0·188 and 0·438 grm.

With the tables given below :—

10 cc. of a 20 per cent. solution of sample will be suitable for 2·5–10 per cent. invert sugar on sample.

10 cc. of a 10 per cent. solution of sample will be suitable for 5–20 per cent. invert sugar on sample.

5 cc. of a 10 per cent. solution of sample will be suitable for 10–40 per cent. invert sugar on sample.

50 cc. of Fehling's solution are mixed with an amount of water such that, with the sugar solution to be added subsequently, the total volume = 100 cc. The beaker containing the mixture is covered with a watch-glass and placed in a boiling water-bath for 20 minutes, at the end of which time the sugar solution is added, and the beaker left in the boiling water-bath for exactly 12 minutes. At the end of this time the precipitate of Cu_2O is filtered through asbestos in a Gooch crucible, washed, dried, ignited by placing the Gooch crucible inside a larger ordinary crucible, and weighed.

The invert sugar is calculated from the CuO according to the following table of Brown, Morris and Millar:—

Dextrose grm.	Cu grm.	CuO grm.	Cu equivalent to 1 grm. Dextrose.	Lævulose grm.	Cu grm.	CuO grm.	Cu Equivalent to 1 grm. Lævulose.	Invert sugar grm.	Cu grm.	CuO grm.
0.050	0.1030	0.1289	2.060	0.050	0.0923	0.1155	1.846	0.050	0.0975	0.1221
0.055	0.1134	0.1422	2.061	0.055	0.1027	0.1287	1.858	0.055	0.1076	0.1349
0.060	0.1238	0.1552	2.063	0.060	0.1122	0.1407	1.870	0.060	0.1176	0.1474
0.065	0.1342	0.1682	2.062	0.065	0.1216	0.1524	1.871	0.065	0.1275	0.1598
0.070	0.1443	0.1809	2.061	0.070	0.1312	0.1645	1.874	0.070	0.1373	0.1721
0.075	0.1543	0.1935	2.058	0.075	0.1405	0.1761	1.873	0.075	0.1468	0.1840
0.080	0.1644	0.2061	2.055	0.080	0.1500	0.1881	1.875	0.080	0.1566	0.1963
0.085	0.1740	0.2187	2.046	0.085	0.1590	0.1993	1.871	0.085	0.1662	0.2084
0.090	0.1834	0.2299	2.038	0.090	0.1686	0.2114	1.873	0.090	0.1755	0.2200
0.095	0.1930	0.2420	2.033	0.095	0.1774	0.2224	1.868	0.095	0.1848	0.2317
0.100	0.2027	0.2538	2.027	0.100	0.1862	0.2331	1.862	0.100	0.1941	0.2430
0.105	0.2123	0.2662	2.024	0.105	0.1952	0.2447	1.859	0.105	0.2034	0.2550
0.110	0.2218	0.2781	2.020	0.110	0.2040	0.2558	1.855	0.110	0.2128	0.2668
0.115	0.2313	0.2900	2.012	0.115	0.2129	0.2669	1.851	0.115	0.2220	0.2783
0.120	0.2404	0.3014	2.003	0.120	0.2215	0.2777	1.846	0.120	0.2311	0.2898
0.125	0.2496	0.3130	1.997	0.125	0.2303	0.2887	1.843	0.125	0.2400	0.3009
0.130	0.2585	0.3241	1.990	0.130	0.2390	0.2997	1.840	0.130	0.2489	0.3121
0.135	0.2675	0.3354	1.981	0.135	0.2477	0.3106	1.834	0.135	0.2578	0.3232
0.140	0.2762	0.3463	1.973	0.140	0.2559	0.3209	1.828	0.140	0.2663	0.3339
0.145	0.2850	0.3573	1.964	0.145	0.2641	0.3311	1.822	0.145	0.2750	0.3448
0.150	0.2934	0.3673	1.956	0.150	0.2723	0.3409	1.815	0.150	0.2832	0.3546
0.155	0.3020	0.3787	1.948	0.155	0.2805	0.3517	1.811	0.155	0.2915	0.3655
0.160	0.3103	0.3891	1.940	0.160	0.2889	0.3622	1.806	0.160	0.3002	0.3764
0.165	0.3187	0.3996	1.931	0.165	0.2972	0.3726	1.803	0.165	0.3086	0.3869
0.170	0.3268	0.4098	1.922	0.170	0.3053	0.3828	1.799	0.170	0.3167	0.3971
0.175	0.3350	0.4200	1.914	0.175	0.3134	0.3930	1.793	0.175	0.3251	0.4076
0.180	0.3431	0.4302	1.906	0.180	0.3216	0.4032	1.787	0.180	0.3331	0.4177
0.185	0.3508	0.4399	1.896	0.185	0.3297	0.4134	1.782	0.185	0.3410	0.4276
0.190	0.3590	0.4501	1.890	0.190	0.3377	0.4234	1.777	0.190	0.3490	0.4376
0.195	0.3668	0.4599	1.881	0.195	0.3457	0.4335	1.773	0.195	0.3570	0.4476
0.200	0.3745	0.4689	1.872	0.200	0.3539	0.4431	1.769	0.200	0.3650	0.4570
0.205	0.3822	0.4792	1.863	0.205	0.3616	0.4534	1.765	0.205	0.3726	0.4672

Note:—In commercial sugars there is a small amount of non-sugar substance which reduces Fehling's solution, and in accurate analysis this must be allowed for. (See next page.)

Preparation of Basic Lead Acetate

3 parts of lead acetate and 1 part of litharge are well mixed with $\frac{1}{2}$ part of water, and heated on the water-bath until the original yellow mixture has become reddish. The remainder to make 10 parts of water is added, the mixture allowed to settle, and filtered. The filtrate should be clear and colourless, and of Sp. Gr. 1·235–1·240.

Preparation of Alumina Cream.

A 10 per cent. solution of alum is precipitated with ammonia, the precipitate filtered and washed free from ammonia, after which it is suspended in water to form a cream

Correction for non-sugar substances which reduce Fehling's solution :—The principle is to ferment away sugars with brewers' yeast and to determine the reducing power after fermentation ; the CuO so determined has been produced by non-sugar substances. The method adopted for ascertaining the reducing power previous to fermentation must also be used for the determination after fermentation, and the details as to quantities will vary accordingly.

The following is an example of the determination of non-sugar reducing substances according to the method of Brown, Morris and Millar.

50 cc. of 10 per cent. sugar solution (= 5 grm.) are sterilised by boiling for a few minutes, allowed to cool (covered with a watch-glass), about 2 grm. of washed and pressed brewers' yeast added, and the mixture allowed to ferment at about 75°F. (24°C.) in a thermostat. When fermentation is complete (about 48—72 hours), a small amount of alumina cream is added, and the whole washed into a 100 cc. flask and made up to the mark at 60°F.

On 25 cc. (= 1·25 grm. original sample) of the clear filtrate the reducing power is determined, and on another portion the rotation in a 2 dm. tube is found.

The CuO × 80 gives the CuO reduced by the non-sugar substances in 100 grm. of the sample.

DETERMINATION OF INVERT SUGAR BY CLERGET METHOD.

The percentage of sucrose is first determined by the Clerget method as under determination of cane sugar by inversion

method (*a*), the direct reading before inversion being determined after clarifying the solution with lead acetate and alumina cream.

$$\text{Per cent. invert sugar} = \frac{(\% \text{ sucrose} - D) \ 105\cdot3}{44 - \frac{t}{2}}$$

where D = direct reading corresponding to normal weight.

II. Determination of the Cane Sugar in Commercial Products.

1. *Soleil-Ventzke-Scheibler polarimeter method, using Schmitz's table* (following page).

This method is used for determining sucrose in beetroot juice, in "thin juice," and in the Weinberg method of estimating the apparent purity of the crude juice from the sugar cane.

100 cc. of the juice is introduced into a flask which is graduated to hold 100 and 110 cc. and basic lead acetate added to give a total volume of 110 cc., the mixture is well shaken and filtered. In the case of beetroot juice the solution after shaking is allowed to stand for 10-15 minutes before filtering. The rotation of the filtrate in a 200 mm. tube increased by 10%, multiplied by 0·26, and divided by the sp. gr. gives the % of sugar by weight.

Schmitz's table (see next page) renders this calculation unnecessary.

2. *Inversion Method.*

(*a*) *Using the Saccharimeter* (Clerget's method).

Half the normal weight (13 grm.) is dissolved in 75 cc. water in a 100 cc. flask, and 5 cc. HCl of Sp. Gr. 1·188 added. The flask is placed in a water-bath at 70°C., and the contents maintained constant at 67-70°C. for exactly 5 mins., cooled to 20°C. and diluted to the mark. If the solutions are dark, 1-2 grm. bone charcoal (previously extracted with HCl and ignited) is added, the flasks well shaken, and the solutions filtered until clear and colourless. The reading is taken in a jacketed observation tube at 20°C. The solution used for the direct reading before inversion should be clarified with

lead acetate and alumina cream to precipitate active non-sugar substances.

$$\text{Per cent. sucrose} = \frac{100\,S}{142\cdot966 - \frac{t}{2}} \qquad \lfloor\text{Clerget's formula}\rfloor.$$

S = the change in rotation in saccharimeter degrees, calculated on the whole normal weight (26 grm.).

The following formula is used in case raffinose is present, and is applicable only when the solution contains negligible traces of invert sugar.

$$\text{Per cent. sucrose} = \frac{0\cdot5124\,P - I_{20}}{0\cdot839}$$

P = the direct polarisation and I_{26} = the polarisation at $20°C$. after inversion calculated to the whole normal weight.

$$I_{20} = I_t + 0\cdot0038\,S\,(20 - t).$$

Percentage Content of

for observed densities and rotations, with the Soleil-Ventzke-Scheibler
of Sugar, and also the addition of 1/10

Brix 0·5—12·0		Rotation degrees.	Brix and corresponding Sp. Gr.									
Tenths of degree	% Sugar		0·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0
			1·0019	1·0039	1·0058	1·0078	1·0098	1·0117	1·0137	1·0157	1·0177	1·0197
0·1	0·03	1	0·29	0·29	0·29	0·28	0·28	0·28	0·28	0·28	0·28	0·28
0·2	0·06	2		0·57	0·57	0·57	0·57	0·56	0·56	0·56	0·56	0·56
0·3	0·08	3		0·85	0·85	0·85	0·85	0·85	0·85	0·84	0·84	0·84
0·4	0·11	4			1·14	1·13	1·13	1·13	1·13	1·13	1·12	1·12
0·5	0·14	5			1·42	1·42	1·41	1·41	1·41	1·41	1·40	1·40
0·6	0·17	6					1·70	1·70	1·69	1·69	1·68	1·68
0·7	0·19	7					1·98	1·98	1·97	1·97	1·96	1·96
0·8	0·22	8						2·26	2·26	2·26	2·25	2·24
0·9	0·25	9							2·54	2·53	2·53	2·52
		10							2·82	2·81	2·81	2·80
		11								3·10	3·09	3·08
		12								3·38	3·37	3·36
		13								3·66	3·65	3·64
		14								3·94	3·93	3·92
Brix 6·0—12·0		15									4·21	4·20
		16									4·49	4·48
Tenths of degree	% Sugar	17										4·77
		18										
		19										
		20										
0·1	0·03	21										
0·2	0·06	22										
0·3	0·08	23										
0·4	0·11	24										
0·5	0·14	25										
0·6	0·17	26										
0·7	0·19	27										
0·8	0·22	28										
0·9	0·25	29										
		30										
		31										
		32										
		33										
		34										
		35										

Sucrose Solutions (Schmitz)

Polarimeter, taking into consideration the variable Specific Rotatory Power volume of lead acetate solution.

Brix and corresponding Sp. Gr.										Rotation degrees	Brix 12·5—20·0	
											Tenths of degree.	% Sugar.
5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0			
1·0217	1·0237	1·0258	1·0278	1·0298	1·0319	1·0339	1·0360	1·0381	1·0401			
0·28	0·28	0·28	0·28	0·28	0·28	0·28	0·28	0·28	0·28	1	0·1	0·03
0·56	0·56	0·56	0·56	0·55	0·55	0·55	0·55	0·55	0·55	2	0·2	0·05
0·84	0·84	0·84	0·83	0·83	0·83	0·83	0·83	0·83	0·82	3	0·3	0·08
1·12	1·12	1·11	1·11	1·11	1·11	1·11	1·10	1·10	1·10	4	0·4	0·11
1·40	1·40	1·39	1·39	1·39	1·38	1·38	1·38	1·38	1·37	5	0·5	0·13
1·68	1·67	1·67	1·67	1·66	1·66	1·66	1·66	1·65	1·65	6	0·6	0·16
1·96	1·95	1·95	1·95	1·94	1·94	1·93	1·93	1·93	1·92	7	0·7	0·19
2·24	2·23	2·23	2·22	2·22	2·22	2·21	2·21	2·20	2·20	8	0·8	0·21
2·52	2·51	2·51	2·50	2·50	2·49	2·49	2·48	2·48	2·47	9	0·9	0·24
2·80	2·79	2·79	2·78	2·78	2·77	2·76	2·76	2·75	2·75	10		
3·08	3·07	3·07	3·06	3·05	3·05	3·04	3·03	3·03	3·02	11		
3·36	3·35	3·34	3·34	3·33	3·32	3·32	3·31	3·30	3·30	12		
3·64	3·63	3·62	3·61	3·61	3·60	3·59	3·59	3·58	3·57	13		
3·92	3·91	3·90	3·89	3·88	3·88	3·87	3·86	3·85	3·85	14	Brix 12·5—20·0	
4·19	4·19	4·18	4·17	4·16	4·15	4·15	4·14	4·13	4·12	15	Tenths of degree.	% Sugar.
4·47	4·47	4·46	4·45	4·44	4·43	4·42	4·41	4·40	4·40	16		
4·76	4·75	4·74	4·73	4·72	4·71	4·70	4·69	4·68	4·67	17		
5·03	5·02	5·01	5·00	4·99	4·99	4·97	4·97	4·96	4·95	18		
5·32	5·31	5·29	5·28	5·27	5·26	5·25	5·24	5·23	5·22	19		
	5·58	5·57	5·56	5·55	5·54	5·53	5·52	5·51	5·50	20	0·1	0·03
	5·86	5·85	5·84	5·83	5·82	5·81	5·79	5·78	5·77	21	0·2	0·05
		6·13	6·12	6·11	6·09	6·08	6·07	6·06	6·05	22	0·3	0·08
		6·41	6·40	6·38	6·37	6·36	6·35	6·33	6·32	23	0·4	0·11
			6·67	6·66	6·65	6·64	6·62	6·61	6·60	24		
				6·94	6·93	6·91	6·90	6·89	6·87	25	0·5	0·13
				7·22	7·20	7·19	7·17	7·16	7·15	26	0·6	0·16
					7·48	7·46	7·45	7·44	7·42	27	0·7	0·18
					7·76	7·74	7·73	7·71	7·70	28	0·8	0·21
						8·02	8·00	7·99	7·97	29	0·9	0·23
							8·28	8·26	8·25	30		
							8·55	8·54	8·52	31		
							8·83	8·81	8·80	32		
								9·08	9·07	33		
									9·35	34		
									9·62	35		

Brix 0.5—12.0			Brix and corresponding Sp. Gr.									
Tenths of degree.	% Sugar.	Rotation degrees.	10·5	11·0	11·5	12·0	12·5	13·0	13·5	14·0	14·5	15·0
			1·0422	1·0443	1·0464	1·0485	1·0506	1·0528	1·0549	1·0570	1·0592	1·0613
0·1	0·03	1	0·28	0·27	0·27	0·27	0·27	0·27	0·27	0·27	0·27	0·27
0·2	0·06	2	0·55	0·55	0·55	0·55	0·55	0·54	0·54	0·54	0·54	0·54
0·3	0·08	3	0·82	0·82	0·82	0·82	0·82	0·81	0·81	0·81	0·81	0·81
0·4	0·11	4	1·10	1·10	1·09	1·09	1·09	1·09	1·08	1·08	1·08	1·08
0·5	0·14	5	1·37	1·37	1·36	1·36	1·36	1·36	1·35	1·35	1·35	1·35
0·6	0·17	6	1·64	1·64	1·64	1·64	1·63	1·63	1·62	1·62	1·62	1·62
0·7	0·19	7	1·92	1·91	1·91	1·91	1·91	1·90	1·89	1·89	1·89	1·88
0·8	0·22	8	2·19	2·19	2·18	2·18	2·18	2·17	2·17	2·16	2·16	2·15
0·9	0·25	9	2·47	2·46	2·46	2·45	2·45	2·44	2·44	2·43	2·43	2·42
		10	2·74	2·74	2·73	2·73	2·72	2·71	2·71	2·70	2·70	2·69
		11	3·02	3·01	3·00	3·00	2·99	2·99	2·98	2·97	2·97	2·96
		12	3·29	3·28	3·28	3·27	3·26	3·26	3·25	3·24	3·24	3·23
		13	3·56	3·56	3·55	3·54	3·54	3·53	3·52	3·51	3·51	3·50
		14	3·84	3·83	3·83	3·82	3·82	3·81	3·80	3·79	3·78	3·77
Brix 6·0—12·0		15	4·11	4·11	4·10	4·09	4·08	4·07	4·06	4·06	4·05	4·04
		16	4·39	4·38	4·37	4·36	4·35	4·34	4·33	4·33	4·32	4·31
Tenths of degree.	% Sugar.	17	4·66	4·65	4·64	4·63	4·62	4·62	4·61	4·60	4·59	4·58
		18	4·93	4·93	4·91	4·91	4·90	4·89	4·88	4·87	4·86	4·85
		19	5·21	5·20	5·19	5·18	5·17	5·16	5·15	5·14	5·13	5·12
		20	5·49	5·47	5·46	5·45	5·44	5·43	5·42	5·41	5·40	5·39
0·1	0·03	21	5·76	5·75	5·74	5·73	5·71	5·70	5·69	5·68	5·67	5·66
0·2	0·06	22	6·03	6·02	6·01	6·00	5·99	5·97	5·96	5·95	5·94	5·93
0·3	0·08	23	6·31	6·30	6·28	6·27	6·26	6·24	6·23	6·22	6·21	6·20
0·4	0·11	24	6·58	6·57	6·56	6·54	6·53	6·52	6·50	6·49	6·48	6·46
0·5	0·14	25	6·86	6·84	6·83	6·82	6·80	6·79	6·78	6·76	6·75	6·73
0·6	0·17	26	7·13	7·12	7·10	7·09	7·07	7·06	7·05	7·03	7·02	7·00
0·7	0·19	27	7·41	7·39	7·38	7·36	7·35	7·33	7·32	7·30	7·29	7·27
0·8	0·22	28	7·68	7·66	7·65	7·63	7·62	7·60	7·59	7·57	7·56	7·54
0·9	0·25	29	7·96	7·94	7·92	7·91	7·89	7·87	7·86	7·84	7·83	7·81
		30	8·23	8·21	8·20	8·18	8·16	8·15	8·13	8·11	8·10	8·08
		31	8·50	8·49	8·47	8·45	8·44	8·42	8·40	8·39	8·37	8·35
		32	8·78	8·76	8·74	8·73	8·71	8·69	8·67	8·66	8·64	8·62
		33	9·05	9·03	9·02	9·00	8·98	8·96	8·94	8·93	8·91	8·89
		34	9·33	9·31	9·29	9·27	9·25	9·23	9·22	9·20	9·18	9·16
		35	9·60	9·58	9·56	9·54	9·53	9·51	9·49	9·47	9·45	9·43
		36	9·88	9·86	9·84	9·82	9·80	9·78	9·76	9·74	9·72	9·70
		37	10·15	10·13	10·11	10·09	10·07	10·05	10·03	10·01	9·99	9·97
		38		10·40	10·38	10·36	10·34	10·32	10·30	10·28	10·26	10·24
		39		10·68	10·66	10·64	10·61	10·59	10·57	10·55	10·53	10·51

	Brix and corresponding Sp. Gr.									Rotation degrees.	Brix 12·5—20·0	
15·5	16·0	16·5	17·0	17·5	18·0	18·5	19·0	19·5	20·0		Tenths of degree.	% Sugar
10·635	1·0657	1·0678	1·0700	1·0722	1·0744	1·0766	1·0788	1·0811	1·0833			
0·27	0·27	0·27	0·27	0·27	0·27	0·27	0·27	0·27	0·26	1	0·1	)·03
0·54	0·54	0·54	0·53	0·53	0·53	0·53	0·53	0·53	0·53	2	0·2	)·05
0·81	0·80	0·80	0·80	0·80	0·80	0·80	0·79	0·79	0·79	3	0·3	)·08
1·08	1·07	1·07	1·07	1·07	1·06	1·06	1·06	1·06	1·06	4	0·4	0·11
1·34	1·34	1·34	1·34	1·33	1·33	1·33	1·32	1·32	1·32	5	0·5	0·13
1·61	1·61	1·61	1·60	1·60	1·60	1·59	1·59	1·59	1·58	6	0·6	0·16
1·88	1·88	1·87	1·87	1·86	1·86	1·86	1·85	1·85	1·85	7	0·7	0·19
2·15	2·15	2·14	2·14	2·13	2·13	2·12	2·12	2·12	2·11	8	0·8	0·21
2·42	2·41	2·41	2·40	2·40	2·39	2·39	2·38	2·38	2·37	9	0·9	0·24
2·69	2·68	2·68	2·67	2·67	2·66	2·65	2·65	2·64	2·64	10		
2·95	2·95	2·94	2·94	2·93	2·92	2·92	2·91	2·91	2·90	11		
3·22	3·22	3·21	3·20	3·20	3·19	3·18	3·18	3·17	3·17	12		
3·49	3·49	3·48	3·47	3·46	3·46	3·45	3·44	3·44	3·43	13		
3·76	3·75	3·75	3·74	3·73	3·72	3·72	3·71	3·70	3·69	14	Brix 12·5—20·0	
4·03	4·02	4·02	4·01	4·00	3·99	3·98	3·97	3·97	3·96	15	Tenths of degree.	% Sugar.
4·30	4·29	4·28	4·27	4·26	4·26	4·25	4·24	4·23	4·22	16		
4·57	4·56	4·55	4·54	4·53	4·52	4·51	4·50	4·49	4·48	17		
4·84	4·83	4·82	4·81	4·80	4·79	4·78	4·77	4·76	4·75	18		
5·11	5·10	5·09	5·08	5·06	5·05	5·04	5·03	5·02	5·01	19		
5·38	5·36	5·35	5·34	5·33	5·32	5·31	5·30	5·29	5·28	20		
5·65	5·63	5·62	5·61	5·60	5·59	5·58	5·56	5·55	5·54	21	0·1	0·03
5·91	5·90	5·89	5·88	5·87	5·85	5·85	5·83	5·82	5·80	22	0·2	0·05
6·18	6·17	6·16	6·14	6·13	6·12	6·11	6·09	6·08	6·07	23	0·3	0·08
6·45	6·44	6·43	6·41	6·40	6·39	6·37	6·36	6·35	6·33	24	0·4	0·11
6·72	6·71	6·69	6·68	6·67	6·65	6·64	6·63	6·61	6·60	25	0·5	0·13
6·99	6·97	6·96	6·95	6·93	6·92	6·90	6·89	6·88	6·86	26	0·6	0·16
7·26	7·24	7·23	7·21	7·20	7·18	7·17	7·15	7·14	7·13	27	0·7	0·18
7·53	7·51	7·50	7·48	7·47	7·45	7·44	7·42	7·40	7·39	28	0·8	0·21
7·80	7·78	7·77	7·75	7·73	7·72	7·70	7·68	7·67	7·65	29	0·9	0·23
8·06	8·05	8·03	8·02	8·00	7·98	7·97	7·95	7·93	7·92	30		
8·33	8·32	8·30	8·28	8·27	8·25	8·23	8·21	8·20	8·18	31		
8·60	8·58	8·57	8·55	8·53	8·51	8·50	8·48	8·46	8·45	32		
8·87	8·85	8·84	8·82	8·80	8·78	8·76	8·75	8·73	8·71	33		
9·14	9·12	9·10	9·09	9·07	9·05	9·03	9·01	8·99	8·97	34		
9·41	9·39	9·37	9·35	9·34	9·31	9·30	9·28	9·26	9·24	35		
9·68	9·66	9·64	9·62	9·60	9·58	9·56	9·54	9·52	9·50	36		
9·95	9·93	9·91	9·89	9·87	9·85	9·83	9·81	9·79	9·77	37		
10·22	10·20	10·18	10·15	10·13	10·11	10·09	10·07	10·05	10·03	38		
10·49	10·46	10·44	10·42	10·40	10·38	10·36	10·34	10·32	10·29	39		

Brix 11.5—22.5		Rotation degrees.	Brix and corresponding Sp. Gr.							
Tenths of degree.	% Sugar.		11·5	12·0	12·5	13·0	13·5	14·0	14·5	15·0
			1·0464	1·0485	1·0506	1·0528	1·0549	1·0570	1·0592	1·0613
		40	10·93	10·91	10·89	10·86	10·84	10·82	10·80	10·78
0·1	0·03	41		11·18	11·16	11·14	11·12	11·09	11·07	11·05
0·2	0·05	42		11·46	11·43	11·41	11·39	11·36	11·34	11·32
0·3	0·08	43			11·71	11·68	11·66	11·64	11·61	11·59
0·4	0·11	44			11·98	11·95	11·93	11·91	11·88	11·86
0·5	0·13	45			12·25	12·23	12·20	12·18	12·15	12·13
0·6	0·16	46				12·50	12·47	12·45	12·42	12·40
0·7	0·19	47					12·74	12·72	12·69	12·67
0·8	0·21	48					13·02	12·99	12·97	12·94
0·9	0·24	49						13·26	13·23	13·21
		50							13·50	13·48
		51							13·78	13·75
		52								14·02
		53								14·29
		54								

Brix 17.0—23.0		Rotation degrees.
Tenths of degree.	% Sugar.	
		55
		56
		57
		58
		59
0·1	0·03	60
0·2	0·05	61
0·3	0·08	62
0·4	0·11	63
		64
0·5	0·13	65
0·6	0·16	66
0·7	0·18	67
0·8	0·21	68
0·9	0·24	69
		70
		71
		72
		73
		74
		75
		76
		77
		78
		79
		80

Brix and corresponding Sp. Gr.									Rotation degrees	Brix 23·0—24·0	
15·5	16·0	16·5	17·0	17·5	18·0	18·5	19·0	19·5		Tenths of degree	% Sugar
1·0635	1·0657	1·0678	1·0700	1·0722	1·0744	1·0766	1·0788	1·0811			
10·76	10·73	10·71	10·69	10·67	10·64	10·62	10·60	10·58	40	0·1	0·03
11·03	11·00	10·98	10·96	10·94	10·91	10·89	10·87	10·85	41	0·2	0·05
11·29	11·27	11·25	11·23	11·20	11·18	11·16	11·13	11·11	42	0·3	0·08
11·56	11·54	11·52	11·49	11·47	11·45	11·42	11·40	11·38	43	0·4	0·10
11·83	11·81	11·79	11·76	11·74	11·71	11·69	11·66	11·64	44		
12·10	12·08	12·05	12·03	12·01	11·98	11·96	11·93	11·91	45	0·5	0·13
12·37	12·35	12·32	12·30	12·27	12·25	12·22	12·20	12·17	46	0·6	0·16
12·64	12·61	12·59	12·56	12·54	12·51	12·49	12·46	12·44	47	0·7	0·18
12·91	12·88	12·86	12·83	12·81	12·78	12·75	12·73	12·70	48	0·8	0·21
13·18	13·15	13·13	13·10	13·07	13·05	13·02	12·99	12·97	49	0·9	0·23
13·45	13·42	13·40	13·37	13·34	13·31	13·29	13·26	13·23	50		
13·72	13·69	13·66	13·64	13·61	13·58	13·55	13·52	13·50	51		
13·99	13·96	13·93	13·90	13·88	13·85	13·82	13·79	13·76	52		
14·26	14·23	14·20	14·17	14·14	14·11	14·08	14·05	14·03	53		
14·58	14·50	14·47	14·44	14·41	14·38	14·35	14·32	14·29	54	Brix 23·5—24·0	
14·80	14·77	14·74	14·71	14·68	14·65	14·62	14·59	14·56	55	Tenths of degree	% Sugar
	15·03	15·00	14·97	14·94	14·91	14·88	14·85	14·82	56		
	15·30	15·27	15·24	15·21	15·18	15·15	15·12	15·09	57		
	15·54	15·51	15·48	15·45	15·42	15·38	15·35		58		
	15·81	15·78	15·75	15·71	15·68	15·65	15·62		59		
		16·05	16·01	15·98	15·95	15·92	15·88		60		
		16·31	16·28	16·25	16·21	16·18	16·15		61	0·1	0·03
			16·55	16·52	16·48	16·45	16·41		62	0·2	0·05
			16·82	16·78	16·75	16·71	16·68		63	0·3	0·08
				17·05	17·01	16·98	16·94		64	0·4	0·10
				17·32	17·28	17·24	17·21		65	0·5	0·13
					17·55	17·51	17·47		66	0·6	0·16
					17·81	17·78	17·74		67	0·7	0·18
						18·04	18·00		68	0·8	0·21
						18·31	18·27		69	0·9	0·23
							18·53		70		
									71		
									72		
									73		
									74		
									75		
									76		
									77		
									78		
									79		
									80		

Brix 23·0—24·0 Tenths of degree	% Sugar	Rotation degrees	Brix and corresponding Sp. Gr. 20·0	20·5	21·0	21·5	22·0	22·5	23·0	23·5	24·0
			1·0833	1·0855	1·0878	1·0900	1·0923	1·0946	1·0969	1·0992	1·1015
		40	10·56	10·54	10·52	10·49	10·47	10·45	10·43	10·41	10·38
0·1	0·03	41	10·82	10·80	10·78	10·76	10·74	10·71	10·69	10·67	10·65
0·2	0·05	42	11·09	11·07	11·04	11·02	11·00	10·97	10·95	10·93	10·90
0·3	0·08	43	11·35	11·33	11·31	11·28	11·26	11·24	11·21	11·19	11·17
0·4	0·11	44	11·62	11·59	11·57	11·55	11·52	11·50	11·47	11·45	11·42
0·5	0·13	45	11·88	11·86	11·83	11·81	11·78	11·76	11·73	11·71	11·69
0·6	0·16	46	12·15	12·12	12·09	12·07	12·05	12·02	12·00	11·97	11·94
0·7	0·18	47	12·41	12·39	12·36	12·33	12·31	12·28	12·26	12·23	12·21
0·8	0·21	48	12·67	12·65	12·62	12·60	12·57	12·54	12·52	12·49	12·47
0·9	0·23	49	12·94	12·91	12·88	12·86	12·83	12·81	12·78	12·75	12·73
		50	13·20	13·18	13·15	13·12	13·09	13·07	13·04	13·01	12·99
		51	13·47	13·44	13·41	13·39	13·36	13·33	13·30	13·27	13·25
		52	13·73	13·70	13·68	13·65	13·62	13·59	13·56	13·53	13·51
		53	14·00	13·97	13·94	13·91	13·88	13·85	13·82	13·79	13·77
		54	14·26	14·23	14·20	14·17	14·14	14·11	14·08	14·04	14·02
Brix 23·0—24·0 Tenths of degree	% Sugar	55	14·53	14·50	14·47	14·44	14·41	14·38	14·35	14·32	14·29
		56	14·79	14·76	14·73	14·70	14·67	14·64	14·61	14·58	14·55
		57	15·06	15·02	14·99	14·96	14·93	14·90	14·87	14·84	14·81
		58	15·32	15·29	15·26	15·23	15·19	15·16	15·13	15·10	15·07
		59	15·58	15·55	15·52	15·49	15·46	15·42	15·39	15·36	15·33
		60	15·85	15·82	15·78	15·75	15·72	15·69	15·65	15·62	15·59
0·1	0·03	61	16·11	16·08	16·05	16·01	15·98	15·95	15·91	15·88	15·85
0·2	0·05	62	16·38	16·35	16·31	16·28	16·24	16·21	16·18	16·14	16·11
0·3	0·08	63	16·64	16·61	16·57	16·54	16·51	16·47	16·44	16·40	16·37
0·4	0·10	64	16·91	16·87	16·84	16·80	16·77	16·73	16·70	16·66	16·63
0·5	0·13	65	17·17	17·14	17·10	17·07	17·03	17·00	16·96	16·92	16·89
0·6	0·16	66	17·44	17·40	17·37	17·33	17·29	17·26	17·22	17·19	17·15
0·7	0·18	67	17·70	17·67	17·63	17·59	17·56	17·52	17·48	17·45	17·41
0·8	0·21	68	17·97	17·93	17·89	17·86	17·82	17·78	17·74	17·71	17·67
0·9	0·23	69	18·23	18·19	18·16	18·12	18·08	18·04	18·00	17·97	17·93
		70	18·50	18·46	18·42	18·38	18·34	18·31	18·27	18·23	18·19
		71	18·76	18·72	18·68	18·65	18·61	18·57	18·53	18·49	18·45
		72	19·03	18·99	18·95	18·91	18·87	18·83	18·79	18·75	18·71
		73		19·25	19·21	19·17	19·13	19·09	19·05	19·01	18·97
		74		19·52	19·48	19·44	19·40	19·35	19·31	19·27	19·23
		75		19·78	19·74	19·70	19·66	19·62	19·57	19·53	19·49
		76			20·00	19·96	19·92	19·88	19·84	19·80	19·75
		77			20·27	20·22	20·18	20·14	20·10	20·06	20·01
		78				20·49	20·45	20·40	20·36	20·32	20·27
		79				20·75	20·71	20·66	20·62	20·58	20·54
		80					20·97	20·93	20·88	20·84	20·80

(b) Using Polarimeter graduated in circular degrees.

Acid inversion method.

The reading on a 10 " per cent." solution, containing 10 grm. in 100 cc. solution, is taken at 20°C. in a 2 dm. tube. 25 cc. of a 20 per cent. solution are placed in a 50 cc. flask, 2·5 grm. of citric acid added and the liquid boiled for 10 minutes. Davis and Daish have shown that cane sugar is completely hydrolysed by boiling with a 10 per cent. solution of citric acid for 10 minutes. After inversion the solution is neutralised and made up to 50 cc., giving a solution equivalent to a 10-per cent. solution of the original sample. If necessary the liquid should be decolorised. A reading is now taken in a 2 dm. tube at 20°C.

$$\text{Per cent. sucrose in sample} = \frac{C \times 10}{1 \cdot 755}$$

C = total change in reading in *circular* degrees due to inversion, calculated on 10 per cent. solution, in a 2 dm. tube.

Invertase (Yeast) Inversion Method.

The principle is exactly the same as in the acid inversion method, except that yeast is used to invert the sucrose.

A reading is taken before inversion on a 10 per cent. solution in a 2 dm. tube; 25 cc. of a 20 per cent. solution is measured into a 50 cc. flask, 0·5 grm. of washed pressed yeast added after the solution has been brought to 50°C. (122°F.), and the mixture maintained at 50—53°C. for 6 hours, after which alumina cream is added, and the mixture cooled and diluted to 50 cc. The reading on the filtrate is taken in a 2 dm. tube, and the per cent. sucrose in the sample calculated by the formula given above.

The yeast inversion is more accurate than acid inversion, since lævulose is very sensitive to acid, by which it is easily destroyed; the acid method, however, takes much less time.

3. *Gravimetric Determination of the Sucrose in Cane Sugars.*

1. CuO due to invert sugar, etc., already present in sample: generally 20 cc. of a 10 per cent. solution is a suitable quantity

2. CuO from 10 cc. of a 2 per cent. solution after inversion of the sucrose.

Method of Inversion.

25 cc. water, 1 cc. concentrated hydrochloric acid, and 10 cc. of the 10 per cent. sugar solution are placed in a 100 cc. flask. The whole is raised to 65-66°C. in a water bath and maintained constant at this temperature for 20 minutes, after which it is cooled and 2·5 cc. 4N NaOH added

to neutralise the acid; the contents are now diluted to 100 cc., well shaken, and the copper reduction determined on 20 cc. (= 0·2 grm. original sugar) by the Brown, Morris and Millar method. This method should also be used for the other copper reduction required for this determination of sucrose.

CuO due to invert sugar from sucrose
= total CuO after inversion − CuO due to invert sugar, etc.

$$C_{12}H_{22}O_{11} + H_2O = \underbrace{C_6H_{12}O_6 + C_6H_{12}O_6}$$

342	360
sucrose	invert sugar
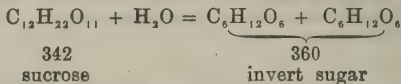
Per cent sucrose = $500 \times \dfrac{352}{360} \times$ invert sugar in 0·2 grm.

2. Invert Sugar.

This is met with commercially in the form of very stiff pastes which also contain a smaller or larger amount of uninverted sucrose.

(1) The invert sugar is determined by the Brown, Morris and Millar method given under "Cane Sugar."

10 cc. of the 10 per cent. solution of invert sugar is diluted to 50 cc.; of this 10 cc. (= 0·2 grm.) are taken for the Cu reduction.

The CuO due to non-sugar substances must be determined and allowed for before stating the percentage of invert sugar in the sample.

(2) The sucrose is determined by any of the inversion methods given under "Cane Sugar."

For some purposes it is desired to know the actual amount of lævulose and dextrose in the sample; the amounts of these two sugars are not as a rule equal, the lævulose is usually several per cent (5–6) lower than dextrose; this is due to the comparative ease with which lævulose is destroyed by acid during the acid inversion process used in manufacture.

Determination of Dextrose and Lævulose in Invert Sugars.

The following are required:—

1. The CuO (corrected for non-sugars) produced by 100 grm. of the sample. This is calculated from the CuO produced by 0·2 grm. of the sample, already ascertained in the determination of invert sugar in (1).
2. The rotation in 2 dm. tube (circular degrees), on a 10 per cent. solution.
3. The percentage of sucrose in the sample.
4. The rotation in 2 dm. tube (on solution equivalent to original 10 per cent. solution) after fermentation = **reading due to non-sugars.**

If   W   = weight of Cu reduced by 0·2 grm. sample.

    W_2 = weight of Cu reduced by non-sugars in 0·2 grm. sample.

    C   = weight of sucrose in 100 cc. 10 per cent. solution.

    R   = reading in 2 dm. tube on 10 per cent. solution.

    R_n = reading in 2 dm. tube on 10 per cent. solution after fermentation.

Cu reduced by the dextrose and lævulose in 100 grm. of the sample = $500 (W - W_n)$.

$$[a]_D = \frac{a \times 100}{c \times l} \qquad [a]_D = \text{specific rotatory power (S.R.P.)}$$

a = reading in circular degrees in a tube l dm. long on a solution containing c grm. per 100 cc.

    C grm. sucrose in 100 cc. 10 per cent. solution of sample gives a reading of a in 2 dm. tube.

$$66·5 = \frac{a \times 100}{C \times 2} \quad \text{and} \quad a = \frac{66·5 \times C \times 2}{100} = 1·33 \, C$$

Reading due to dextrose and lævulose in 2 dm. tube 10 per cent. solution = $R - R_n + 1·33 \, C$

The S.R.P. or $[a]_D$ of the sample due to dextrose and lævulose is given by

$$\frac{(R - R_n + 1·33 \, C) \; 100}{2 \times 10}.$$

On referring to Brown, Morris and Millar's table, the gram value of dextrose and lævulose with a reduction of R grams of Cu is found.

    If G_D = the gram value of dextrose,

         G_L = the gram value of lævulose;

         D = the percentage of dextrose in the sample,

         L = the percentage of lævulose in the sample;

then $G_D \, D + G_L \, L = 500 (W - W_n)$,

and $52·8 \, D + (- 92·0 \, L) = 100 \times \dfrac{(R - R_n + 1·33 \, C) \; 100}{2 \times 10}.$

3. Starch Sugar or Glucose.

This is prepared commercially by the acid hydrolysis of starch, and consists essentially of dextrose generally containing a small amount of maltose and dextrin.

Determinations required :

1. R_s = Cu reduction on 0·2 grm.
2. R_n = Cu reduction on 0·2 grm. after fermentation, determined on 1·25 grm. and calculated to 0·2 grm.
3. O_s = Rotation in 2 dm. tube on 10 per cent. solution.
4. O_n = Rotation in 2 dm. tube on 10 per cent. solution after fermentation ; this reading is due to dextrin and non-sugar substances.

G_D = the gram value of dextrose with a reduction of R_s for which the table of Brown, Morris and Millar is used.

G_M = the gram value of maltose with a reduction of R_s, obtained from the following table of Brown, Morris and Millar.

D = the percentage of dextrose in the sample.

M = the percentage of maltose in the sample.

(1) $\quad G_D\,D + G_M\,M = 500\,(R_s - R_n)$

and (2) $\quad 52{\cdot}8\,D + 138{\cdot}0\,M = \dfrac{100 \times (O_s - O_n) \times 100}{2 \times 10}$

TABLE SHOWING THE RELATION BETWEEN Cu, CuO, AND MALTOSE. (From Brown, Morris, and Millar. *J.C.S.*, 1897, **71**, 100.)

Maltose grm.	Cu grm.	CuO grm.	Cu equivt. to 1 grm. Maltose.	Maltose grm.	Cu grm.	CuO grm.	Cu equivt. to 1 grm. Maltose.
.070	.0772	.0966	1.1029	.190	.2072	.2593	1.0953
.075	.0826	.1034	1.1026	.195	.2126	.2661	1.0949
.080	.0880	.1102	1.1023	.200	.2180	.2729	1.0946
.085	.0934	.1169	1.1020	.205	.2234	.2797	1.0943
.090	.0988	.1237	1.1017	.210	.2288	.2865	1.0940
.095	.1042	.1305	1.1013	.215	.2342	.2933	1.0937
.100	.1097	.1373	1.1010	.220	.2397	.3000	1.0933
.105	.1151	.1441	1.1007	.225	.2451	.3068	1.0930
.110	.1205	.1509	1.1004	.230	.2505	.3136	1.0927
.115	.1259	.1576	1.1001	.235	.2559	.3203	1.0924
.120	.1313	.1644	1.0997	.240	.2613	.3272	1.0921
.125	.1367	.1712	1.0994	.245	.2667	3340	1.0917
.130	.1422	.1779	1.0991	.250	.2722	.3407	1.0914
.135	.1476	.1848	1.0988	.255	.2776	.3475	1.0911
.140	.1530	.1916	1.0985	.260	.2830	.3543	1.0908
.145	.1584	.1983	1.0981	.265	.2884	.3610	1.0905
.150	.1634	.2051	1.0978	.270	.2938	.3678	1 0901
.155	.1692	.2119	1.0975	.275	.2992	.3747	1.0898
.160	.1747	.2186	1.0972	.280	.3047	.3814	1.0895
.165	.1801	.2254	1.0969	.285	.3101	.3882	1.0892
.170	.1855	.2323	1.0965	.290	.3155	.3950	1.0889
.175	.1909	.2490	1.0962	.295	.3209	.4017	1.0885
.180	.1963	.2458	1.0959	.300	.3264	.4085	1.0882
.185	.2017	.2526	1.0956	.305	.3318	.4154	1.0879

Additional Determinations for all Commercial Sugars.

(1) *Ash.* Determined on 5 grm. of the sample by careful charring in a platinum dish and finally igniting to a white ash.

(2) *Moisture.* Carbohydrates generally are extremely difficult to obtain anhydrous, special drying apparatus, including P_2O_5, being required; for technical work where a number of such determinations are necessary, this method of drying is excluded. The conventional method is as follows :—

The Sp. Gr. of a 10 per cent. solution (*i.e.*, 10 grm. in 100 cc. solution) is determined with the Sp. Gr. bottle or Sprengel tube and referred to water=1000. Excess Sp. Gr. over 1000 divided by 3·86 gives the dry solids in 100 cc. solution (=10 grm. of sample), and these multiplied by 10 the total dry solids per cent. on the sample (= T.S.).

$$100 - \text{T.S.} = \text{per cent. moisture.}$$

The ash, however, introduces an error, for while 1 grm. of sugar in 100 cc. solution gives a Sp. Gr. of 1003·86, 1 grm. of ash in 100 cc. gives a Sp. Gr. of 1008·0, *i.e.* about twice that of sugar; therefore, to correct for the ash, the per cent. ash is subtracted from the solids first found, which leaves the real T.S. and hence the moisture.

(3) *Proteins.* By the ordinary Kjeldahl method on 4–5 grm. of the sample. N is calculated to protein by the factor 6·25 or 6·3, according to different investigators.

The proteins in sugars are usually only small in amount, and it is absolutely essential to do a blank with each fresh stock of reagents.

The methods detailed apply to technical products which seldom, with the exception of the high grade cane sugars, consist of one sugar or even sugar and water alone; such methods are naturally complicated, but if the product under investigation is known to consist of one sugar and water or to contain only one sugar together with other inactive bodies then the methods may be very much simplified, and in such cases either the Sp. Gr., the S.R.P., or reducing power of the product may be sufficient.

The sum of the total sugars, moisture, ash, and protein, deducted from 100 gives the *Unfermentable Matter* per cent., returned as such without reference to its nature.

SPECIFIC ROTATORY POWERS OF SUGARS.

p = grm. in 100 grm. solution.
C = grm. in 100 cc.

Sugar.	Authority.	$[\alpha]_D$	°C.	Concentration.	Solution Factor.
Lævulose.	——	- 92.25	20	p=10	—
	Ling, Eynon, & Lane	- 93.83	18.5	C=10	—
	Brown.	- 92.0	20	C=10	See next table
	Briant.	- 92.0	20	C=10	3.86
Maltose.	Brown, Morris, and Milla.	+138.0	20	C=10	3.86
	Ling, Eynon, & Lane	+137.8	17.5	C= 5.7	—
	——	+136.8	20	C=10	—
Invert.	——	- 27.9	0	C=17.2	—
	——	- 20.05	15	—	—
		0	87.2		
Lactose	——	52.5	20	p= 5.7	—
Dextrose.	——	51.7	15°	C= 3	—
	Brown.	52.8	20	C=10	See next table
	Briant.	51.7	—	C=10	3.86
	Ling, Eynon & Lane	52.72	17°	C=10	—
Sucrose.	——	66.6	20	p= 4.18	—
	Brown.	66.6	20	C=10	See next table
	Briant	66.5	—	C=10	3.86

Tuchschmid gives the following for the S.R.P. of invert sugar at any temperature :

$$[\alpha]_D = (27.9° - 0.32t).$$

$[\alpha]_j$ is the S.R.P. for the "medium yellow" of the spectrum, and is equal to $[\alpha]_D \times 1.111$.

One form of Schmidt and Haensch half-shadow polarimeter has a straight scale of 100 divisions. The reading 100 is given in 2 dm. tube by a solution containing 26.048 grm. of sucrose in 100 cc. solution at 17.5° C., i.e., when this amount of the sugar sample is dissolved and made up to 100 cc. the reading gives directly the per cent. sucrose in the sample, just as in the Soleil-Ventzke-Scheibler polarimeter.

Each scale division = 0.3459 of a degree Laurent (circular degrees) for all ordinary sugars other than sucrose, and = 0.3469 of a degree for sucrose.

To convert divisions into degrees [α], multiply by 0·3854 for sucrose, and by 0·3843 for other sugars.

In cases where the solution is too deep in colour for direct observation the colour may usually be precipitated by adding a few drops of basic lead acetate or of alumina cream before diluting the solution to the mark, avoiding unnecessary excess, which tends to carry down sugar; generally 5 drops per 50 cc. of 10 per cent. solution are sufficient. If this treatment fails. animal charcoal may be employed.

Solution Factors of Sugars.

The use of these has been described under "Moisture in sugar." However one factor is not absolutely correct for all sugars, nor is it correct for one sugar at all concentrations, but notwithstanding this, the factor 3·86 is used by general convention for all sugars for technical purposes.

In case the correct solution factor is required for any specific sugar at a certain concentration, it may be obtained from a graph given by Brown, Morris and Millar, (*J.C.S.*, 1897, **71**, 72) from which the following table is compiled :—

DIVISORS FOR SUGARS AT VARIOUS DENSITIES.

Sp. Gr. at 15.5°C.	Dextrose.	Sucrose.	Invert Sugar.	Lævulose.	Maltose.
1010	3.845	3.869	3.895	3.940	3.938
20	3.841	3.867	3.892	3.932	3.934
30	3.837	3.865	3.890	3.925	3.929
40	3.832	3.863	3.887	3.918	3.924
50	3.827	3.860	3.884	3.910	3.919
60	3.821	3.857	3.881	3.903	3.913
70	3.814	3.854	3.878	3.895	3.907
·80	3.807	3.850	3.875	3.887	3.902
90	3.799	3.847	3.872	3.880	3.895
1100	3.791	3.842	3.869	3.871	3.889
10	—	—	3.865	—	3.883
20	—	—	3.862	—	3.876
30	—	—	3.858	—	3.869
40	—	—	3.854	—	3.862

Conversion of Saccharometer Readings to Specific Gravities (Mategczek and Scheibler).

Balling's Saccharometer, improved by Brix, gives directly
°Brix = Percentage of sugar.

The following table refers to Sp. Gr. of solution at 17·5°C compared to water at 17·5°C. = 1.

°Brix.	Sp. Gr.	°Brix.	Sp. Gr.	°Brix.	Sp. Gr.
0.0	1.00000	8.4	1.03352	16.8	1.06914
0.2	0077	8.6	3434	17.0	7002
0.4	0155	8.8	3517	17.2	7090
0.6	0232	9.0	3599	17.4	7177
0.8	0310	9.2	3682	17.6	7265
1.0	0388	9.4	3765	17.8	7353
1.2	0466	9.6	3848	18.0	7441
1.4	0544	9.8	3931	18.2	7530
1.6	0622	10.0	4014	18.4	7618
1.8	0701	10.2	4097	18.6	7706
2.0	0779	10.4	4180	18.8	7795
2.2	0858	10.6	4264	19.0	7884
2.4	0936	10.8	4348	19.2	7973
2.6	1015	11.0	4431	19.4	8062
2.8	1094	11.2	4515	19.6	8151
3.0	1173	11.4	4599	19.8	8240
3.2	1252	11.6	4683	20.0	8329
3.4	1332	11.8	4768	20.2	8419
3.6	1411	12.0	4852	20.4	8509
3.8	1491	12.2	4937	20.6	8599
4.0	1570	12.4	5021	20.8	8688
4.2	1650	12.6	5106	21.0	8778
4.4	1730	12.8	5191	21.2	8869
4.6	1810	13.0	5276	21.4	8959
4.8	1890	13.2	5361	21.6	9049
5.0	1970	13.4	5446	21.8	9140
5.2	2051	13.6	5532	22.0	9231
5.4	2131	13.8	5617	22.2	9321
5.6	2211	14.0	5703	22.4	9412
5.8	2292	14.2	5789	22.6	9503
6.0	2373	14.4	5874	22.8	9595
6.2	2454	14.6	5960	23.0	9686
6.4	2535	14.8	6047	23.2	9777
6.6	2616	15.0	6133	23.4	9869
6.8	2697	15.2	6219	23.6	9961
7.0	2779	15.4	6306	23.8	1.10053
7.2	2860	15.6	6392	24.0	0145
7.4	2942	15.8	6479	24.2	0237
7.6	3024	16.0	6566	24.4	0329
7.8	3105	16.2	6653	24.6	0421
8.0	3187	16.4	6740	24.8	0514
8.2	3270	16.6	6827	25.0	0607

°Brix.	Sp. Gr.	°Brix.	Sp. Gr.	°Brix.	Sp. Gr.
25.2	1.10700	34.4	1.15113	43.6	1.19822
25.4	0793	34.6	5213	43.8	9927
25.6	0886	34.8	5312	44.0	1.20033
25.8	0979	35.0	5411	44.2	0139
26.0	1072	35.2	5511	44.4	0245
26.2	1166	35.4	5611	44.6	0352
26.4	1259	35.6	5710	44.8	0458
26.6	1353	35.8	5810	45.0	0565
-26.8	1447	36.0	5911	45.2	0672
27.0	1541	36.2	6011	45.4	0779
27.2	1635	36.4	6111	45.6	0886
27.4	1729	36.6	6212	45.8	0993
27.6	1824	36.8	6313	46.0	1100
27.8	1918	37.0	6413	46.2	1208
28.0	2013	37.2	6514	46.4	1315
28.2	2107	37.4	6616	46.6	1423
28.4	2202	37.6	6717	46.8	1531
28.6	2297	37.8	6818	47.0	1639
28.8	2393	38.0	6920	47.2	1747
29.0	2488	38.2	7022	47.4	1856
29.2	2583	38.4	7123	47.6	1964
29.4	2679	38.6	7225	47.8	2073
29.6	2775	38.8	7327	48.0	2182
29.8	2871	39.0	7430	48.2	2291
30.0	2967	39.2	7532	48.4	2400
30.2	3063	39.4	7635	48.6	2509
30.4	3159	39.6	7737	48.8	2619
30.6	3255	39.8	7840	49.0	2728
30.8	3352	40.0	7943	49.2	2838
31.0	3449	40.2	8046	49.4	2948
31.2	3545	40.4	8150	49.6	3058
31.4	3642	40.6	8253	49.8	3168
31.6	3740	40.8	8357	50.0	3278
31.8	3837	41.0	8460	50.2	3389
32.0	3934	41.2	8564	50.4	3499
32.2	4032	41.4	8668	50.6	3610
32.4	4129	41.6	8772	50.8	3721
32.6	4227	41.8	8877	51.0	3832
32.8	4325	42.0	8981	51.2	3943
33.0	4423	42.2	9086	51.4	4055
33.2	4521	42.4	9190	51.6	4166
33.4	4620	42.6	9295	51.8	4278
33.6	4718	42.8	9400	52.0	4390
33.8	4817	43.0	9505	52.2	4502
34.0	4915	43.2	9611	52.4	4614
34.2	5014	43.4	9716	52.6	4726

°Brix.	Sp. Gr.	°Brix.	Sp. Gr.	°Brix.	Sp. Gr.
52.8	1.24839	62.0	1.30177	71.2	1.35847
53.0	4951	62.2	0297	71.4	5974
53.2	5064	62.4	0416	71.6	6101
53.4	5177	62.6	0536	71.8	6228
53.6	5290	62.8	0657	72.0	6355
53.8	5403	63.0	0777	72.2	6483
54.0	5517	63.2	0897	72.4	6611
54.2	5630	63.4	1018	72.6	6739
54.4	5744	63.6	1139	72.8	6867
54.6	5857	63.8	1260	73.0	6995
54.8	5971	64.0	1381	73.2	7124
55.0	6086	64.2	1502	73.4	7252
55.2	6200	64.4	1624	73.6	7381
55.4	6314	64.6	1745	73.8	7510
55.6	6429	64.8	1867	74.0	7639
55.8	6544	65.0	1989	74.2	7768
56.0	6658	65.2	2111	74.4	7898
56.2	6773	65.4	2233	74.6	8027
56.4	6889	65.6	2355	74.8	8157
56.6	7004	65.8	2478	75.0	8287
56.8	7120	66.0	2601	75.2	8417
57.0	7235	66.2	2724	75.4	8547
57.2	7351	66.4	2847	75.6	8677
57.4	7464	66.6	2970	75.8	8808
57.6	7583	66.8	3093	76.0	8939
57.8	7699	67.0	3217	76.2	9070
58.0	7816	67.2	3340	76.4	9201
58.2	7932	67.4	3464	76.6	9332
58.4	8049	67.6	3588	76.8	9463
58.6	8166	67.8	3712	77.0	9595
58.8	8283	68.0	3836	77.2	9726
59.0	8400	68.2	3961	77.4	9858
59.2	8518	68.4	4085	77.6	9990
59.4	8635	68.6	4210	77.8	1.40122
59.6	8753	68.8	4335	78.0	0254
59.8	8871	69.0	4460	78.2	0387
60.0	8989	69.2	4585	78.4	0520
60.2	9107	69.4	4711	78.6	0652
60.4	9225	69.6	4836	78.8	0785
60.6	9343	69.8	4962	79.0	0918
60.8	9462	70.0	5088	79.2	1052
61.0	9581	70.2	5214	79.4	1185
61.2	9700	70.4	5450	79.6	1318
61.4	9819	70.6	5466	79.8	1452
61.6	9938	70.8	5593	80.0	1586
61.8	1.30057	71.0	5720	80.2	1720

°Brix.	Sp. Gr.	°Brix.	Sp. Gr.	°Brix.	Sp. Gr.
80.4	1.41854	85.4	1.45262	90.4	1.48771
80.6	1989	85.6	5401	90.6	8913
80.8	2123	85.8	5539	90.8	9056
81.0	2258	86.0	5678	91.0	9199
81.2	2393	86.2	5817	91.2	9342
81.4	2528	86.4	5956	91.4	9485
81.6	2663	86.6	6095	91.6	9628
81.8	2798	86.8	6235	91.8	9771
82.0	2934	87.0	6374	92.0	9915
82.2	3070	87.2	6514	92.2	1.50058
82.4	3205	87.4	6654	92.4	0202
82.6	3341	87.6	6794	92.6	0346
82.8	3478	87.8	6934	92.8	0491
83.0	3614	88.0	7074	93.0	0635
83.2	3750	88.2	7215	93.2	0779
83.4	3887	88.4	7356	93.4	0924
83.6	4024	88.6	7496	93.6	1069
83.8	4161	88.8	7637	93.8	1214
84.0	4298	89.0	7778	94.0	1359
84.2	4435	89.2	7920	94.2	1504
84.4	4573	89.4	8061	94.4	1649
84.6	4710	89.6	8203	94.6	1795
84.8	4848	89.8	8345	94.8	1941
85.0	4986	90.0	8486	95.0	2087
85.2	5124	90.2	8629		

Conversion of Specific Gravities at 17·5°C to Saccharometer Degrees. (Balling).

Headings of column give fourth decimal figure of Sp. Gr.
° Balling = % Cane Sugar in the solution.

	0	1	2	3	4	5	6	7	8	9
1.008	2.000	2.025	2.050	2.075	2.100	2.125	2.150	2.175	2.200	2.225
1.009	2.250	2.275	2.300	2.325	2.350	2.375	2.400	2.425	2.450	2.475
1.010	2.500	2.525	2.550	2.575	2.600	2.625	2.650	2.675	2.700	2.725
1.011	2.750	2.775	2.800	2.825	2.850	2.875	2.900	2.925	2.950	2.975
1.012	3.000	3.025	3.050	3.075	3.100	3.125	3.150	3.175	3.200	3.225
1.013	3.250	3.275	3.300	3.325	3.350	3.375	3.400	3.425	3.450	3.475
1.014	3.500	3.525	3.550	3.575	3.600	3.625	3.650	3.675	3.700	3.725
1.015	3.750	3.775	3.800	3.825	3.850	3.875	3.900	3.925	3.950	3.975
1.016	4.000	4.025	4.050	4.075	4.100	4.125	4.150	4.175	4.200	4.225
1.017	4.250	4.275	4.300	4.325	4.350	4.375	4.400	4.425	4.450	4.475
1.018	4.500	4.525	4.550	4.575	4.600	4.625	4.650	4.675	4.700	4.725
1.019	4.750	4.775	4.800	4.825	4.850	4.875	4.900	4.925	4.950	4.975

	0	1	2	3	4	5	6	7	8	9
1.020	5.000	5.025	5.050	5.075	5.100	5.125	5.150	5.175	5.200	5.225
1.021	5.250	5.275	5.300	5.325	5.350	5.375	5.400	5.425	5.450	5.475
1.022	5.500	5.525	5.550	5.575	5.600	5.625	5.650	5.675	5.700	5.725
1.023	5.750	5.775	5.803	5.825	5.850	5.875	5.900	5.925	5.950	5.975
1.024	6.000	6.024	6.048	6.073	6.097	6.122	6.146	6.170	6.195	6.219
1.025	6.244	6.268	6.292	6.316	6.341	6.365	6.389	6.413	6.438	6.463
1.026	6.488	6.512	6.536	6.560	6.584	6.609	6.633	6.657	6.681	6.706
1.027	6.731	6.756	6.780	6.804	6.828	6.853	6.877	6.901	6.925	6.950
1.028	6.975	7.000	7.024	7.048	7.073	7.097	7.122	7.146	7.170	7.195
1.029	7.219	7.244	7.268	7.292	7.316	7.341	7.365	7.389	7.413	7.438
1.030	7.463	7.488	7.512	7.536	7.560	7.584	7.609	7.633	7.657	7.681
1.031	7.706	7.731	7.756	7.780	7.804	7.828	7.853	7.877	7.901	7.925
1.032	7.950	7.975	8.000	8.024	8.048	8.073	8.097	8.122	8.146	8.170
1.033	8.195	8.219	8.244	8.268	8.292	8.316	8.341	8.365	8.389	8.413
1.034	8.438	8.463	8.488	8.512	8.536	8.560	8.584	8.609	8.633	8.657
1.035	8.681	8.706	8.731	8.756	8.780	8.804	8.828	8.853	8.877	8.901
1.036	8.925	8.950	8.975	9.000	9.024	9.048	9.073	9.097	9.122	9.146
1.037	9.170	9.195	9.219	9.244	9.268	9.292	9.316	9.341	9.365	9.389
1.038	9.413	9.438	9.463	9.488	9.512	9.536	9.560	9.584	9.609	9.633
1.039	9.657	9.681	9.706	9.731	9.756	9.780	9.804	9.828	9.853	9.877
1.040	9.901	9.925	9.950	9.975	10.000	10.023	10.047	10.071	10.095	10.119
1.041	10.142	10.166	10.190	10.214	10.238	10.261	10.285	10.309	10.333	10.357
1.042	10.381	10.404	10.428	10.452	10.476	10.500	10.523	10.547	10.571	10.595
1.043	10.618	10.642	10.666	10.690	10.714	10.738	10.761	10.785	10.809	10.833
1.044	10.857	10.881	10.904	10.928	10.952	10.976	11.000	11.023	11.047	11.071
1.045	11.095	11.119	11.142	11.166	11.190	11.214	11.238	11.261	11.285	11.309
1.046	11.333	11.357	11.381	11.404	11.428	11.452	11.476	11.500	11.523	11.547
1.047	11.571	11.595	11.619	11.642	11.666	11.690	11.714	11.738	11.761	11.785
1.048	11.809	11.833	11.857	11.881	11.904	11.928	11.952	11.976	12.000	12.023
1.049	12.047	12.071	12.095	12.119	12.142	12.166	12.190	12.214	12.283	12.261
1.050	12.285	12.309	12.333	12.357	12.381	12.404	12.428	12.452	12.476	12.500
1.051	12.523	12.547	12.571	12.595	12.619	12.642	12.666	12.690	12.714	12.738
1.052	12.761	12.785	12.809	12.833	12.857	12.881	12.904	12.928	12.952	12.976
1.053	13.000	13.023	13.047	13.071	13.095	13.119	13.142	13.166	13.190	13.214
1.054	13.238	13.261	13.285	13.309	13.333	13.357	13.381	13.404	13.428	13.452
1.055	13.476	13.500	13.523	13.547	13.571	13.595	13.619	13.642	13.666	13.690
1.056	13.714	13.738	13.761	13.785	13.809	13.833	13.857	13.881	13.904	13.928
1.057	13.952	13.976	14.000	14.023	14.047	14.071	14.095	14.119	14.142	14.166
1.058	14.190	14.214	14.238	14.261	14.285	14.309	14.333	14.357	14.381	14.404
1.059	14.428	14.452	14.476	14.500	14.523	14.547	14.571	14.595	14.619	14.642
1.060	14.666	14.690	14.714	14.738	14.761	14.785	14.809	14.833	14.857	14.881
1.061	14.904	14.928	14.952	14.976	15.000	15.023	15.046	15.070	15.093	15.116
1.062	15.139	15.162	15.186	15.209	15.232	15.255	15.278	15.302	15.325	15.348
1.063	15.371	15.395	15.418	15.441	15.464	15.488	15.511	15.534	15.557	15.581
1.064	15.604	15.627	15.650	15.674	15.697	15.721	15.744	15.767	15.790	15.814
1.065	15.837	15.860	15.883	15.907	15.930	15.953	15.976	16.000	16.023	16.046

	0	1	2	3	4	5	6	7	8	9
1.066	16.070	16.093	16.116	16.139	16.162	16.186	16.209	16.232	16.255	16.278
1.067	16.302	16.325	16.348	16.371	16.395	16.418	16.441	16.464	16.488	16.510
1.068	16.534	16.557	16.581	16.604	16.627	16.650	16.674	16.697	16.721	16.744
1.069	16.767	16.790	16.814	16.837	16.860	16.883	16.907	16.930	16.953	16.976
1.070	17.000	17.022	17.045	17.067	17.090	17.113	17.136	17.158	17.181	17.204
1.071	17.227	17.250	17.272	17.295	17.318	17.340	17.363	17.386	17.409	17.431
1.072	17.454	17.477	17.500	17.522	17.545	17.568	17.590	17.613	17.636	17.659
1.073	17.681	17.704	17.727	17.750	17.772	17.795	17.818	17.841	17.863	17.886
1.074	17.909	17.931	17.954	17.977	18.000	18.022	18.045	18.067	18.090	18.113
1.075	18.137	18.158	18.181	18.204	18.227	18.250	18.272	18.295	18.318	18.340
1.076	18.363	18.386	18.409	18.431	18.454	18.477	18.500	18.522	18.545	18.569
1.077	18.590	18.613	18.636	18.659	18.681	18.704	18.724	18.750	18.772	18.795
1.078	18.818	18.841	18.863	18.886	18.909	18.931	18.954	18.977	19.000	19.022
1.079	19.045	19.067	19.090	19.113	19.136	19.158	19.181	19.204	19.227	19.250

Correction of Saccharometer Readings to 17·5°C.
(Sachs).

°C.	\ Degrees Brix of Solution												
	0	5	10	15	20	25	30	35	40	50	60	70	75
0	− 0.27	0.30	0.41	0.52	0.62	0.72	0.82	0.92	0.98	1.11	1.22	1.25	1.29
5	0.23	0.30	0.37	0.44	0.52	0.59	0.65	0.72	0.75	0.80	0.88	0.91	0.94
10	0.20	0.26	0.29	0.33	0.36	0.39	0.42	0.45	0.48	0.50	0.54	0.58	0.61
11	0.18	0.23	0.26	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.47	0.50	0.53
12	0.16	0.20	0.22	0.24	0.26	0.29	0.31	0.33	0.34	0.36	0.40	0.42	0.46
13	0.14	0.18	0.19	0.21	0.22	0.24	0.26	0.27	0.28	0.29	0.33	0.35	0.39
14	0.12	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.22	0.23	0.26	0.28	0.32
15	0.09	0.11	0.12	0.14	0.14	0.15	0.16	0.17	0.16	0.17	0.19	0.21	0.25
16	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.12	0.14	0.16	0.18
17	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06
18	+0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
19	0.06	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.06
20	0.11	0.14	0.15	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.18	0.15	0.11
21	0.16	0.20	0.22	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.25	0.22	0.18
22	0.21	0.26	0.29	0.31	0.31	0.32	0.32	0.32	0.33	0.34	0.32	0.29	0.25
23	0.27	0.32	0.35	0.37	0.38	0.39	0.39	0.39	0.40	0.42	0.39	0.36	0.33
24	0.32	0.38	0.41	0.43	0.44	0.46	0.46	0.47	0.47	0.50	0.46	0.43	0.40
25	0.37	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.55	0.58	0.54	0.51	0.48
26	0.43	0.50	0.54	0.56	0.58	0.60	0.61	0.62	0.62	0.66	0.62	0.58	0.55
27	0.49	0.57	0.61	0.63	0.65	0.68	0.68	0.69	0.70	0.74	0.70	0.65	0.62
28	0.56	0.64	0.68	0.70	0.72	0.76	0.76	0.78	0.78	0.82	0.78	0.72	0.70
29	0.63	0.71	0.75	0.78	0.79	0.84	0.84	0.86	0.86	0.90	0.86	0.80	0.78
30	0.70	0.78	0.82	0.87	0.87	0.92	0.92	0.94	0.94	0.98	0.94	0.88	0.86
35	1.10	1.17	1.22	1.24	1.30	1.32	1.33	1.35	1.36	1.39	1.34	1.27	1.25
40	1.50	1.61	1.67	1.71	1.73	1.79	1.79	1.80	1.82	1.83	1.78	1.69	1.65

Volumetric Determination of Sugars.

Numerous methods and modifications have been proposed by which sugar may be determined volumetrically. However these methods are not so accurate as the gravimetric or polarimetric methods, which are generally preferred, although volumetric methods find considerable favour in biochemistry.

The following methods may be described :—

1. Fehling-Soxhlet method.
2. Allen's modification of Gerrard's method.
3. Benedict's methods (1907 and 1910).

1. *Fehling-Soxhlet Method.*

To obtain accurate results 10 cc. of the sugar must be equivalent to 10 cc. of Fehling's solution; if less than 10 cc. of sugar solution is required for titration, it must be diluted accordingly.

The Fehling's solution must be standardised so that 10 cc. = 0·05 grm. glucose.

Standard invert sugar solution is prepared by dissolving 0·475 grm. pure sucrose in about 50 cc. water, adding 1 cc. concentrated hydrochloric acid, and warming at 70° C. for 15 minutes, again cooling, neutralising and diluting to 100 cc.

10 cc. of Fehling's solution is brought into a porcelain basin or a small flask, 40 cc. of water added and raised to boiling point. The standard sugar solution is run into the gently boiling Fehling's solution, 1 cc. at a time, allowing complete reduction between each addition. The end-point is the disappearance of the blue colour, or the point at which the clear solution ceases to give a brown colour with Ling and Rendle's indicator.

The strength of the Fehling's solution must be adjusted until 10 cc. of the sugar solution are just reduced by 10 cc. of the Fehling's solution.

10 cc. Fehling's solution then = 0·05 grm. glucose or invert
= 0·0475 grm. sucrose.

The actual sugar determination is carried out essentially as above. The first titration is in the nature of a trial; according to its indication the sugar solution must be diluted or concentrated so that about 10 cc. are required for 10 cc. Fehling's solution.

Ling and Rendle's indicator.

1 grm. $FeSO_4.(NH_4)_2SO_4.6H_2O$ and 1 grm. NH_4CNS are dissolved in 10 cc. of water at 120°F., cooled immediately, and 5 cc. of conc. HCl added The solution may be decolorised by adding a small quantity of zinc dust, but its delicacy is decreased after it has been decolorised several times. For practical purposes the indicator may be too delicate, and it is

recommended to prepare it the day before it is required for use, as it gives the best results after the second decolorisation.

2. *Allen's modification of Gerrard's Method.*

Gerrard observed that the presence of KCN prevents the precipitation of Cu_2O from Fehling's solution when reduced by dextrose, etc.

Allen takes 10 cc. Fehling's solution and 40 cc. water, brings to boiling point, and runs in 5 per cent. potassium cyanide solution until the Fehling's solution is just decolorised, avoiding excess; another 10 cc. of Fehling's solution is now added, only this portion of Fehling's solution is reduced, therefore the preparation requires 0·05 grm. dextrose for its reduction as in the Fehling-Soxhlet method. The 0·5 per cent. (approximately) dextrose, or invert sugar solution, or inverted cane sugar solution is run carefully into the boiling Fehling's solution.

3. *Benedict's Method.*

The special reagent required is prepared as follows :—

   200 grm. $Na_2CO_3.10H_2O$ (or 100 grm. Na_2CO_3),
   200 grm. sodium citrate,
   125 grm. KCNS,

are dissolved in water and made up to about 800 cc. Exactly 18 grm. of pure $CuSO_4.5H_2O$ are dissolved in 100 cc. water and added with constant stirring. 5 cc. of 5 per cent. potassium ferrocyanide solution are then added, and the whole diluted to 1000 cc. The effect of the ferrocyanide is to prevent precipitation of Cu_2O. The solution may be preserved.

25 cc. of Benedict's solution are pipetted into a porcelain basin 25–30 cm. diameter, 10–20 grm. crystallised sodium carbonate (or 5–10 grm. anhydrous sodium carbonate), and a piece of porous earthenware are added. The solution is boiled vigorously and the sugar solution run in until a heavy white precipitate is formed and the blue colour becomes distinctly paler. The sugar is now added carefully to the boiling solution till the blue colour has completely disappeared; towards the end an interval of 30 seconds between the drops of sugar solution should be given; water may be added to replace loss by evaporation.

The sugar solution should be 0·5–1 per cent. as in Fehling-Soxhlet method.

25 cc. reagent = 0·05 grm. dextrose = 0·053 grm. fructose.

Interpretation of Results of Sugar Analysis.

I. Cane Sugar.

All white crystalline sugars and candy contain over 99 per cent. sucrose, and an ash between 0·05 and 0·5 per cent.

The ash of cane sugars from beet contains less calcium and

P_2O_5, but more potassium, than that from cane sugars from the sugar cane.

It is generally stated that 1 part of ash prevents the crystallisation of 5 parts of sugar. Briant states, however, that 1 part of ash prevents the crystallisation of 3·75 parts of sugar. One part of invert sugar prevents the crystallisation of 2 parts of sugar.

ANALYSES OF VARIOUS CANE SUGAR PRODUCTS.

Variety of Cane Sugar.	Sucrose %	Invert %	Ash %	H_2O %	Proteins %	Analyst
Raw Jaggery	76.2	10.5	5.2	4.9	–	L. Briant.
Raw Penang	77.1	10.2	3.2	7.1	–	,,
Raw Egyptian	81.0	3.9	8.3	6.1	–	,,
Egyptian	88.62	4.14	2.83	3.68	–	H. Heron.
,,	88.8	3.9	3.8	3.0	–	F. Robinson.
Mauritius	87.20	5.39	1.95	3.36	–	H. Heron.
Green Syrup	50.40	15.43	3.67	16.91	2.38	L. Briant.
Treacle	34.39	26.30	4.91	17.06	2.53	,,
Molasses	48.0	18.0	1.4	31.1	–	,,
Refined " Moist "	85.24	6.54	1.74	3.57	0.65	,,
American Cane Syrup	34.98	31.79	6.50	23.55	0.81	,,
Sugar Cane	11–16	0.4–1.5	0.5–1.0	–	–	Prinsen Geerligs.
Beet Juice	15	–	0.8	–	1.6	,,
Partially Refined Cane	93.4	–	0.9	1.3	–	F. Robinson.
,, ,,	87.5	6.2	0.8	3.5	–	,,

For brewing purposes partially refined canes are generally used and give a brewer's extract (i.e., brewer's lbs. per 2 cwt. of sugar) of about 84–86. The brewers' extract of a sugar is obtained by multiplying the excess Sp. Gr. over 1000 of a 10 per cent. solution by 2·24.

II. Invert Sugar.

Three qualities are generally produced, being commercial as No. 1, No. 2, and No. 3 invert sugars.

The sucrose (uninverted cane sugar) should be between 0·8 and 2 per cent.

The following are Briant's standards for invert sugars for brewing purposes :—

	No. 1. Per cent.	No. 2. Per cent.
Invert Sugar	>76	>74
Sucrose	< 1.5	< 2.0
Ash	< 1.5	< 2.0
Unfermentable	< 2.5	< 3.0
Fe_2O_3	< 0.005	< 0.025
S.R.P.	> 10	> −7

H. Heron gives the following as average figures for the different qualities. The dextrose and lævulose are expressed separately, and it will be noticed the lævulose is always the lower; this is due to the destructive action of the inverting acid; the difference should not, however, be greater than 5–6 per cent. on a carefully inverted sample :

	No. 1.	No. 2.	No. 3.
Dextrose	38.0	37.0	36.0
Lævulose	36.6	34.8	31.1
Sucrose	2.0	2.0	2.5
Ash	1.5	2.0	3.5
Proteins	0.2	0.4	0.6
Moisture	17.7	18.8	19.8
Unfermentable matter	4.0	4.5	6.5
Extract in brewers' lbs. for 2 cwt.	72.5	72.5	72.0

It should be mentioned that glucose is sometimes added to invert sugar to cheapen the cost of production, for improving the colour, and to assist solidification. The $[\alpha]_D$ gives rapid information in this direction; the addition of glucose decreases the negative rotation.

III. Starch Sugar (Glucose).

This is commercial in the form of chips and syrups. It varies considerably in composition, but for brewing purposes Briant gives the following :

	Per cent
Dextrose and Maltose	>65
Dextrin	1–2
Protein	0.5–1.5
Ash	1–1.7

The following figures are for glucose chips (F. Robinson) :

	Per cent.	Per cent.	Per cent.	Per cent.
Dextrose	68.4	55.9	64.1	63.0
Maltose	9.6	10.3	13.11	15.3
Ash	0.9	1.6	1.09	0.84
Moisture	11.8	14.0	16.17	13.1
Proteins	0.36	0.77		
Unfermentable			5.53	7.8
Dextrin, Gallisin, etc.	8.94	17.43		
Brewers' extract per 224 lbs.	77.0	75.8	73.5	73.0

Glucose and dextrin-maltose syrups are very variable in composition. The ash should be <1.0, and proteins <1.0 per cent., and of sulphites (used for bleaching) there should be as little as possible. Confectioners' glucose syrup is quite colourless.

ANALYSIS OF DEXTRIN MALTOSE SYRUPS. (H. Heron.)

	Per cent.	Per cent.
Maltose	35.13	17.63
Dextrose	19.35	14.32
Dextrin and Unfermentable	24.83	48.60
Ash	0.76	1.01
Proteins	0.85	0.79
Water	19.08	17.65
Brewers' extract per 224 lbs.	–	71.7

4. Determination of Pentoses and Pentosans.

Pentoses, if present alone in solution, can be determined by Fehling's solution, but generally a mixture of carbohydrates is present, and in this case the pentose is estimated by converting into furfural by distillation with hydrochloric acid, combining the furfural with phloroglucinol and weighing the phloroglucide.

Material to give 0.03-0.3 grm. phloroglucide is taken. The apparatus consists of a flask provided with a tap funnel and a connecting tube with a trap leading to a condenser. The weighed quantity is distilled with 100 cc. of 12 per cent. hydrochloric acid at such a rate that 30 cc. pass over in 10 minutes, the distillate being filtered through a small filter paper as collected. When 30 cc. have distilled over 30 cc. of dilute acid are added to the flask from the tap funnel, and the distillation continued another 10 minutes. This addition is continued 12 times, or until about 360 cc. of distillate have been collected. Completion of distillation is tested for by means of aniline acetate on filter paper; when no red colour appears distillation is complete. To the whole of the distillate about double the amount of pure phloroglucinol required, dissolved in 12 per cent. HCl, is added, and the mixture well stirred. The liquid becomes yellow, then green, and finally a precipitate settles out which is first green but subsequently becomes black. The volume is made up to 400 cc., and after standing for 12 hours the precipitate is collected on a weighed filter paper, washed with 150 cc. water, dried at 100° C. for 4 hours, and weighed.

$$\text{Furfural} = (a + 0.0052) \times 0.5185.$$
$$\text{Pentose} = (a + 0.0052) \times 1.0075.$$
$$\text{Pentosan} = (a + 0.0052) \times 0.8866.$$

a = the weight of phloroglucide.
0.0052 = the weight of phloroglucide which remains in solution under the above conditions.

The phloroglucinol used must be free from diresorcinol. This latter gives a violet colour on heating nearly to the boil with a few drops of acetic anhydride, cooling, and adding a few drops of concentrated H_2SO_4.

5. Starch.
Determination of Starch.

1. *Ewer's Method* (1908).

25 cc. of glacial acetic acid is run into a 200 cc. flask without wetting the neck. 5 grm. of the finely-ground material is added, the flask closed, and well shaken until the mixture is uniform. The stopper and neck of the flask are then washed down with a further 20 cc. of glacial acetic acid. The flask is now placed in a boiling water bath for 10 minutes, then 10 cc. of hydrochloric acid (1 in 10) is added, and the flask

Water Content of Starch (Scheibler).

On treatment with alcohol of 90°Tr. (90 per cent. by volume), starch containing more than 11·4 per cent. of water gives up the excess water to the alcohol; starch containing less than 11·4 per cent. of water takes up water from the alcohol.

100 cc. of the above alcohol (83·39 grm.) are shaken with $\frac{3\cdot39}{2} = 41\cdot7$ grm. of starch, and the Sp. Gr. of the filtrate determined.

Sp. Gr. filtrate.	% Water in starch.	Sp. Gr. filtrate.	% Water in starch.	Sp. Gr. filtrate.	% Water in starch.
0.8226	0	0.8455	22	0.8643	44
234	1	465	23	651	45
243	2	474	24	658	46
253	3	484	25	665	47
262	4	493	26	673	48
271	5	502	27	680	49
281	6	511	28	688	50
291	7	520	29	695	51
300	8	529	30	703	52
311	9	538	31	710	53
323	10	547	32	716	54
335	11	555	33	723	55
346	12	563	34	731	56
358	13	571	35	738	57
370	14	579	36	745	58
382	15	587	37	753	59
394	16	595	38	760	60
405	17	603	39	767	61
416	18	612	40	775	62
426	19	620	41	783	63
436	20	627	42	791	64
446	21	635	43	798	65

left in the water-bath for exactly 6 minutes, shaking thoroughly every minute. Hot water is now added, the volume made up to 180 cc., and the mixture is heated for a further 15 minutes in the boiling water bath. The solution is cooled, clarified by adding 2·5 cc. of potassium ferrocyanide, made up to the mark with water, filtered, and polarised. If the filtrate is difficult to obtain clear, a few crystals of zinc sulphate are added to assist clarification.

Ewer found corrections were necessary owing to the presence of optically active bodies other than starch. A "blank" is therefore carried out as follows :—

5 grm. of the finely-ground material are added to 70 cc. of water at about 120°F. in a 100 cc. flask, and the whole thoroughly mixed by vigorous shaking. After digestion at the ordinary temperature for 1 hour, 25 cc. of glacial acetic acid are added and digestion continued for half an hour; after this the temperature is adjusted to 60°F., potassium

Water Content of Starch (Saare).

100 grm. potato starch are rinsed into tared 250 cc. flask, water at 17·5°C. added to the mark, and the flask and contents weighed.

Grm. starch + water.	% water in starch	Grm. starch + water.	% water in starch.	Grm. starch + water.	% water in starch.
289.40	0	281.10	21	272.85	42
289.00	1	280.75	22	272.45	43
288.60	2	280.35	23	272.05	44
288.20	3	279.95	24	271.70	45
287.80	4	279.55	25	271.30	46
287.40	5	279.15	26	270.90	47
287.05	6	278.75	27	270.50	48
286.65	7	278.35	28	270.10	49
286.25	8	278.00	29	269.70	50
285.85	9	277.60	30	269.30	51
285.45	10	277.20	31	268.90	52
285.05	11	276.80	32	268.50	53
284.65	12	276.40	33	268.10	54
284.25	13	276.00	34	267.75	55
283.90	14	275.60	35	267.35	56
283.50	15	275.20	36	266.95	57
283.10	16	274.80	37	266.55	58
282.70	17	274.40	38	266.15	59
282.30	18	274.05	39	265.75	60
281.90	19	273.65	40		
281.50	20	273.25	41		

ferrocyanide added, the mixture diluted to 100 cc., filtered and polarised as before.

For rice starch at 68°F. $[a]_D = 186.07$

For maize starch at 68°F. $[a]_D = 184.19$

on 5 per cent. solutions (the concentration has only a slight influence within reasonable limits).

Thus, if after correction for the blank the $[a]_D$ obtained = 130,

$$\text{Starch in the maize} = \frac{130 \times 100}{184.19} = 70.7 \text{ per cent}$$

2. C. O'Sullivan's Method (1884).

The starch is gelatinised and converted into maltose and dextrin by diastase (cold water extract of malt). Oil and soluble carbohydrates must first be removed.

Method. 5 grm. of the grain are extracted with ether in a Soxhlet to remove fat, after which the residue is transferred to a beaker with 1 litre of cold water, allowed to stand about 24 hours and the clear supernatant liquid decanted through a filter, the residue being washed with water at 35°C. The grain is now transferred to a small beaker, using 40 cc. water, and gradually heated up to boiling in a water-bath, with constant stirring to avoid formation of lumps. After boiling in the bath for about 10 minutes it is cooled to 62.8°C. (145° F.) and 10 cc. of extract of malt added (see below).

A correction for the extract of malt is necessary, therefore 10 cc. of the extract of malt with about 40 cc. water are digested along with the starch experiment, and the same determinations made as with the starch experiment.

The digestions at 62.8°C. (145°F.) are allowed to proceed for about 1 hour until all starch has become hydrolysed and no trace of starch can be detected with iodine; the mixtures are then raised to boiling for 10 minutes, cooled, made up to 200 cc., and filtered through dry paper into dry beakers.

In the filtrates are determined—

    1. The copper reduction by the Brown, Morris and Millar method as given under "Sugar analysis," taking 10 cc. of the converted starch solution.

    2. The rotation in degrees.

Maltose. From the weights of CuO obtained, the maltose is obtained by the table given under analysis of glucose.

Maltose from 5 grm. grain   = M.

Maltose from 10 cc. malt extract = m.

Maltose percentage from grain   = $(M - m) \dfrac{100}{5}$

giving an $[a]_D$ of $(M - m) \dfrac{100}{5} \times \dfrac{138}{100}$

Dextrin.

R = reading in 2 dm. tube after subtracting reading due to malt extract.

$$[\alpha]_D = \frac{R \times 100}{2 \times 2\cdot5}$$

$$[\alpha]_D \text{ due to dextrin} = \frac{R \times 100}{2 \times 2\cdot5} - (M - m)\,\frac{138}{5}$$

$$\% \text{ Dextrin} = \left[\frac{R \times 100}{2 \times 2\cdot5} - (M - m)\,\frac{138}{5}\right]\frac{100}{202}$$

Starch gives an equal quantity of dextrin, and 95 parts starch give 100 parts maltose.

$$\underset{\underset{\text{starch.}}{324}}{C_{12}H_{20}O_{10}} + H_2O = \underset{\underset{\text{maltose.}}{342}}{C_{12}H_{22}O_{11}}$$
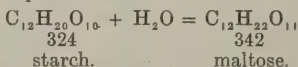
Maltose $\times\ 0\cdot95$ = starch% $\bigg\}$ The total gives the starch
Dextrin $\qquad\quad$ = starch% $\quad$ % in the grain investigated.

3. *H. Brown's Method (Trans. Guinness Research Lab.,* 1903, Vol. I, pt. 1, p. 88).

H. Brown and Heron found that unrestricted diastase always hydrolyses starch to the same stage, namely, that expressed by their "No. 8" equation:

$$\underset{\text{Starch.}}{5(C_{12}H_{20}O_{10})} = \underset{\text{Maltose.}}{4C_{12}H_{22}O_{11}} + \underset{\text{Stable dextrin.}}{(C_{12}H_{20}O_{10})}.$$
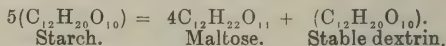
i.e., 100 parts of starch give 84·4 parts of maltose, therefore by determining the maltose after action of unrestricted diastase the amount of starch can be calculated.

2·5 grm. material are placed in the thimble of the extraction apparatus and extracted with alcohol. Alcohol of Sp. Gr. 0·920 is placed in the flask, as the alcohol which then syphons over has the required Sp. Gr. of 0·900, and the temperature inside the extractor remains at 35°–40°C.

The contents of the thimble are then transferred to a beaker and boiled with about 100 cc. of water. After cooling to 57°C. (134°F.), 10 cc. of active malt extract are added and conversion allowed to proceed for 1 hour. The liquid is boiled, filtered into a 200 cc. flask, the residue well washed, and the filtrate and washings made up to 200 cc. The copper-reducing power is determined on 20 cc. by Brown, Morris and Millar's method, and the maltose obtained by their table.

84·4 parts maltose = 100 parts starch, and hence the percentage may be found.

The precautions to be taken are :—

1. Time required for extraction of ready-formed sugars is at least 3 hours for barley and 9 hours for malt.

2. The malt extract should be prepared from a malt dried at 50°–52°C. having a D.A. of 80 Lintner. (See Diastatic activity under "Malt.")

If a malt of higher D.A. is used, about 7–10 per cent. more maltose is obtained, if one of only 40 D.A., then only 81·7 per cent. of maltose is obtained.

4. *Davis and Daish's Method* (1914).

In this method taka-diastase is used to convert the starch completely into glucose and maltose.

The material is extracted with alcohol in a Soxhlet for 18—24 hours; the soluble carbohydrates are generally removed when the extract becomes colourless.

In the case of living plant tissues, etc., the material previous to extraction is plunged into boiling 95 per cent. alcohol containing 1 per cent. by volume of ammonia (0·880); the enzymes are thereby killed. After the Soxhlet extraction such tissues require drying for 18 hours in a steam oven, grinding, and 10 grm. drying to a constant weight in a vacuum at 100°–110°C. over P_2O_5, so as to obtain the weight of dry substance previous to starch estimation.

The dry material from above (or the material from the extraction apparatus if drying not required)—if necessary previously extracted with water for 24 hours, filtered and washed to remove gums, etc.—is gelatinised by heating to the boil (in water-bath) with 200 cc. of water, cooled to 38°C., and 0·1 grm. taka-diastase and 2 cc. of toluene (as an antiseptic) are added, and the mixture left for 24 hours at 38°C. It is then washed by decantation, through a filter, until the filtrate amounts to 475 cc., precipitated with lead acetate, avoiding a large excess (with plant tissues 5·25 cc. required), diluted to 500 cc., and filtered. 100 cc. of the filtrate are precipitated with sodium carbonate and made up to 110 cc., filtered, and the rotation and copper reduction (on 50 cc. by Brown, Morris and Millar method) determined.

From the CuO the total Cu from 100 grm. material is calculated, and the gram values for dextrose and maltose ascertained from Brown, Morris and Millar's tables.

The rotation is calculated to the $[a]_D$ on the material, and from these values the glucose and maltose are calculated by the equations given under starch sugars (glucose).

$$\left. \begin{array}{l} \text{Glucose} \times 0\cdot90 = \text{starch.} \\ \text{Maltose} \times 0\cdot95 = \text{starch.} \end{array} \right\}$$

BREWING MATERIALS.

F. ROBINSON, M.Sc. Tech., B.Sc., F.I.C.

I. Water.

The following determinations are made (in part or completely) :—

Suspended matter.

Free and saline ammonia.

Albuminoid ammonia.

Oxygen absorption.

Nitrites.

⎫
⎬ See " Water Analysis " Section.
⎭

Nitrates.

Examination by Hansen's method.

Examination for *B. coli.*

In addition to the remarks noted under Interpretation of Results (" Water Analysis " section), Sykes and Ling state that as a general rule, neither the free nor the albuminoid NH_3 in a brewing water should exceed 0·1 part per million, and consider that the oxygen absorbed may probably be allowed to rise as high as 0·25 part per 100,000 for brewing purposes. They further consider that in brewing waters the nitrates may rise to 1·5 grains per gallon, and excellent beers have been produced with waters containing 2·5 grains of nitrate per gallon; with such large amounts of nitrates present, the water must be organically pure in other respects.

Nitrates in excess cause rapid weakening of the yeast, apparently due to their reduction to nitrites; they also seem to favour the growth of bacteria at the expense of the yeast. Briant gives as the limits 2·5 grains nitrates per gallon in soft water, and 4 grains in hard water. Waters containing nitrates naturally, *i.e.* not as the result of pollution, are usually hard waters.

Hansen's method of examining brewing waters is sometimes employed, for which the works of Jörgensen, Klöcker, etc., may be consulted.

Factors for Calculating Amount of Water Treatment.

1 fluid oz. satd. $CaCl_2$ soln. (Sp. Gr. 1380) per barrel gives 10 grains $CaCl_2$ per gallon.

1 fluid oz. 45% $MgCl_2$ soln. (Sp. Gr. 1160) per barrel gives 7·5 grains $MgCl_2$ per gallon.

1 ounce $MgSO_4.7H_2O$ per barrel gives 6·0 grains $MgSO_4$ per gallon.

1 ounce $CaSO_4.2H_2O$ (ground gypsum) per barrel gives 9·53 grains $CaSO_4$ per gallon.

A solution of kainit is frequently used to supply both NaCl and $MgSO_4$; the quantity of any such solution required is only decided when its analysis is known.

Water Suitable for Different Types of Beers

As Burton waters have long been noted for the brewing of pale ale, while Dublin and London waters are more suitable for stouts, analyses of these waters are given below in grains per gallon for salts, and parts per million for NH_3 and O_2:

	Burton well water. Briant.	Burton deep well water. Briant.	Burton deep well water. E. Brown.	London Deep well water. Briant.	London Deep well water. Moritz and Morris.	Dublin well. Sykes and Ling.	Water for mild ales. Sykes and Ling.
$NaCl$	9.35	2.54	3.90	10.51	8.54	1.83	35.14
$CaCl_2$							3.88
$CaSO_4$	59.43	63.65	77.87			4.45	6.23
$CaCO_3$			7.62	5.60	5.37	14.21	16.37
K_2SO_4	0.76	0.15	1.59				
$NaNO_3$			1.97				
Na_2SO_4		1.01	10.21	14.14	16.65		
$MgCO_3$	15.83	13.46	21.31	1.47	3.82	0.90	4.01
$SiO_2+Al_2O_3$			0.98		0.30	$SiO_2 = 0.26$ {$Fe_2O_3+Al_2O_3 = 0.24$}	0.22 0.24
$MgSO_4$	6.39	8.97					
$Ca(NO_3)_2$	0.41	1.33			0.69		
Na_2CO_3				10.01	8.25		
NH_3 free	0.015	nil		0.32			
NH_3 albuminoid	0.065	0.050		0.05			
O_2 absorbed	0.790	0.650		0.60			

Quantities of Various Salts in Waters for Various Beers.

Quality of Beer.		Sykes and Ling.	Briant.	Moritz and Morris.	
		Grains per gallon.			
Mild.	NaCl	35	40—75	10—20	—
	CaSO₄	10—20	—	—	—
	MgCl₂	15	—	—	—
	MgSO₄	—	—	—	<5
	CaCl₂	5	—	—	—
Pale and Bitter.	NaCl	—	—	—	<6
	CaCl₂	10	—	—	—
	MgSO₄	—	—	—	6—10
	CaSO₄	40—50	—	—	—

For stouts (*i.e.* black beers) Na_2SO_4 and Na_2CO_3 may be useful, but their addition does not improve a water sufficiently free from $CaSO_4$ and $MgSO_4$; in such a case Na_2CO_3 is added to precipitate $CaSO_4$ and $MgSO_4$.

1 grain $CaSO_4$ requires 2·1 grains $Na_2CO_3.10H_2O$, or 1·28 grains $K_2CO_3.2H_2O$.

1 grain $MgSO_4$ requires 2·38 grains $Na_2CO_3.10H_2O$, or 1·45 grains $K_2CO_3.2H_2O$.

Over 50 grains NaCl per gallon causes weakening of the yeast. (Milk contains about 120 grains per gallon.)

Over 75 grains $CaSO_4$ per gallon causes slow conditioning and clearing.

Ounces per barrel × 12·15 = grains per gallon.

Substances Used in Water Treatment.

Calcium Chloride solution.

The commercial article is a saturated solution, containing an average of 3,600 grains $CaCl_2$ per gallon, with a variation of 3 or 4 per cent.

The Sp. Gr. varies from about 1·360 to 1·395.

Gypsum.

The best form in which to use this is precipitated calcium sulphate in the form of a very stiff paste; this is more easily soluble than ground gypsum, but even in this paste a few hard gritty particles remain (varying in quantity with the sample) more difficult than the main bulk to dissolve. The product varies considerably in moisture; hence the $CaSO_4$ may vary as much as 15 per cent., and it is very desirable that every batch be tested. It is quite possible to maintain the per cent. $CaSO_4$ constant within ± 2 on different batches. Commercial gypsum pastes contain between 43 per cent. and 53 per cent. $CaSO_4$.

A rapid method of determining the moisture is by careful ignition.

Kainit solution.

Pure kainit (K_2SO_4, $MgSO_4$, $MgCl_2.6H_2O$) is not met with commercially, and the product obtained is largely contaminated with NaCl. For use in brewing it is sold as a strong solution of Sp. Gr. about 1·212.

The analysis is carried out by ordinary analytical methods, and the following is a specimen analysis of such a commercial solution.

Kainit solution (F. Robinson).

NaCl	8,580 grains per gallon.	$MgSO_4$ 3,255 grains per gallon.
$MgCl_2$	3,148 ,, ,,	SiO_2 37 ,, ,,
K_2SO_4	5,503 ,, ,,	

2. Malt.
Commercial Methods of Malt Analysis.

The following is an abstract of the Standard Method of Analysis as recommended by the Malt Analysis Committee of the Institute of Brewing (*Journ. Inst. Brew.*, 1906, **12**, 1; 1910, **16**, 529; and 1922, **28**, 775).

PALE MALTS.
Sampling.

In the case of deliveries, samples should be drawn from at least 10 sacks if the consignment amounts to over 100 sacks, or if the parcel be smaller, then from 10 per cent. of the number of sacks. The sample should be drawn, not from the surface of a sack, but with a spear from a depth at least 6 ins. from the surface.

These bulk samples should be put into a large tin kept for the purpose, and well shaken; a smaller tin (at least a pint capacity) is then filled from the larger one, and sent to the analyst, the remainder being reserved in other small tins if the analysis is to be checked. The lids of all tins containing samples for analysis should fit well, and it is desirable to affix gummed paper round the junction of the lid and tin. Well dried and stoppered bottles are more suitable.

In sampling malts from heaps, surface samples should be avoided as in the case of sacks, and six to twelve samples should be withdrawn and mixed in a large tin; a small tin or bottle being filled with a portion of the mixture and sent for analysis. When the malt lies in bins, a sample from the spout will generally fairly represent the bulk if the bin has been drawn upon. If not, the bin should be probed at different depths, five or six samples withdrawn, mixed in a large tin, and a small tin or bottle filled from the mixture and sent for analysis.

Either the " Seck " or the " Boby " mill should be used for all estimations, except that of moisture, where a coffee mill may be employed. The rolls must be checked at 0·5 mm. at

frequent intervals by means of a feeler-gauge. In order to allow for loss in the mill, a quantity of malt, slightly in excess of that required for each determination, is to be separately weighed out and ground. Finally, the exact amounts of grist, subsequently required for the various determinations, are weighed out. It is not permissible to grind at the outset sufficient malt for all the determinations, and to weigh out the various quantities from this grist.

To check the results, the analyst should lay in a stock of a certain malt at the commencement of the season, and each working day the extract, diastatic activity and moisture of this stock malt should be estimated, no results for other samples being accepted when the results with the stock malt show any appreciable divergence from the normal values. The stock malt should be taken from one kilning, and must be kept in an air-tight vessel.

Extract.

54 grm. of malt are ground in the Seck mill, and of the grist exactly 50 grm. are weighed out and washed in a copper, porcelain, or glass beaker with 360 cc. of distilled water previously heated to 155°F. The beaker is covered with a clock-glass and maintained at 150°F. in a water-bath for one hour, stirring at 10 minute intervals. The whole mash is then washed into a 515 cc. flask, cooled to 60°F. and diluted up to 515 mark (the 15 cc. is to allow for the volume occupied by the grains). The flask is well shaken, and the mash filtered, the first 50 cc. being returned. When about 250 cc. have been collected, the Sp. Gr. of the filtrate is determined with the Sp. Gr. bottle at 60°/60°F. The excess Sp. Gr. over water (= 1000) multiplied by 3·36 gives the extract in brewers' lbs. per standard quarter of malt.

If preferred, the mashing can be carried out directly in the 515 cc. measuring flask. In this case the mash should be shaken at intervals of about 10 minutes.

It is more convenient in summer to determine the Sp. Gr. of the wort at $t°/t°$. The correct Sp. Gr. (S. 60°/60°) is related to the apparent Sp. Gr. at $t°$F. (S. $t°/t°$) as follows :

$$\text{S. } 60°/60° = \text{S. } t°/t° + (t-60)\ 0·02.$$

Tint

This is determined in the Lovibond tintometer. The filtrate (wort) from the extract determination, which must be perfectly bright, is placed at once in a 1 in. cell (with glass ends), and its tint recorded in colour units of the series "52" glasses, by comparison in the Lovibond instrument. Direct sunlight should not be used, and the light must fall equally on both halves of the porcelain screen, so that both the cell and comparison glasses are equally illuminated. After noting the

tint, the cell and the comparison glasses should be reversed and another reading taken; with uniform illumination of the screen this reading will be equal to that previously taken.

Moisture.

About 5 grm. of malt are accurately weighed out in a weighing bottle 2 in. in diameter and 1 in. deep, and heated for three hours in a boiling water oven. The loss in weight is taken as the moisture, and the result should be returned as the nearest 0·1%.

SPECIFIC GRAVITY AND CORRESPONDING "EXTRACT."
(Brewers' lbs. per Quarter.)

Sp. Gr. of Wort.	Extract.	Sp. Gr. of Wort.	Extract.	Sp. Gr. of Wort.	Extract.
1022.5	75.6	1025.1	84.3	1027.6	92.7
.6	75.9	.2	84.7	.7	93.0
.7	76.3	.3	85.0	.8	93.4
.8	76.6	.4	85.3	.9	93.7
.9	76.9	.5	85.7	1028.0	94.1
1023.0	77.3	.6	86.0	.1	94.4
.1	77.6	.7	86.3	.2	94.7
.2	77.9	.8	86.7	.3	95.1
.3	78.3	.9	87.0	.4	95.4
.4	78.6	1026.0	87.4	.5	95.7
.5	78.9	.1	87.7	.6	96.1
.6	79.3	.2	88.0	.7	96.4
.7	79.6	.3	88.4	.8	96.7
.8	79.9	.4	88.7	.9	97.1
.9	80.3	.5	89.0	1029.0	97.4
1024.0	80.6	.6	89.4	.1	97.8
.1	81.0	.7	89.7	.2	98.1
.2	81.3	.8	90.0	.3	98.4
.3	81.6	.9	90.4	.4	98.8
.4	81.9	1027.0	90.7	.5	99.1
.5	82.3	.1	91.0	.6	99.5
.6	82.6	.2	91.4	.7	99.9
.7	82.9	.3	91.7	.8	100.1
.8	83.3	.4	92.0	.9	100.5
.9	83.6	.5	92.4	1030.0	100.8
1025.0	84.0				

Diastatic Activity (Lintner Value).

25 grm. of ground malt are extracted with 500 cc. of distilled water for three hours at 70°F., well stirred every half hour, filtered bright, and the first 100 cc. rejected. A portion of the filtrate (3 or 4 cc.) is allowed to act on 100 cc. of a 2 per cent. solution of soluble starch (see below) at 70°F. for one hour in a 200 cc. flask. 10 cc. of N/10 caustic soda is added to stop further diastatic action, the liquid cooled to 60°F. and diluted to 200 cc. with distilled water, shaken well, and titrated against 5 cc. portions of Fehling's solution, using Ling and Rendle's indicator (see Volumetric determination of sugars, "Carbohydrates" Section).

5 cc. of Fehling's solution are measured into a boiling flask,

and raised to the boil over a small Bunsen flame. The converted starch solution is added from a burette, in 5 cc. quantities at first, the mixture being kept rotated and boiled after each addition until reduction of the copper is complete, which is ascertained by rapidly withdrawing a drop of liquid on a glass rod, and bringing it at once in contact with a drop of the indicator on a porcelain spot plate.

$$D.A. = \frac{1000}{XY}$$

D.A. = Diastatic activity.

X = the number of cc. of malt extract contained in 100 cc. of the fully diluted starch conversion liquid.

Y = the number of cc. of same liquid required for the reduction of 5 cc. of Fehling's solution.

The above method (using 3 cc. malt extract to 100 cc. of 2 per cent. soluble starch solution) is not accurate for malts having a diastatic capacity exceeding 50° Lintner; in the case of such malts the relative volume of malt extract must be less, say 2 cc., or, for malts of the highest diastatic capacity, such as are frequently used by distillers and vinegar makers (*i.e.* malts over 80° Lintner), an even smaller volume of extract must be taken.

DIASTATIC ACTIVITY (DEGREES LINTNER).

100 cc. 2 per cent. soluble starch + 4 cc. malt extract per 200 cc.

The table gives the cc. of the diluted starch conversion used in the titration.

cc.	D.P.	cc.	D.P.	cc.	D.P	cc.	D.P.
10.0	50	12.8	39	17.2	29	26.3	19
10.2	49	13.2	38	17.8	28	27.8	18
10.4	48	13.5	37	18.5	27	29.4	17
10.6	47	13.9	36	19.2	26	31.3	16
10.9	46	14.3	35	20.0	25	33.3	15
11.1	45	14.7	34	20.8	24	35.7	14
11.4	44	15.2	33	21.7	23	38.5	13
11.6	43	15.6	32	22.7	22	41.7	12
11.9	42	16.1	31	23.8	21	45.5	11
12.2	41	16.7	30	25.0	20	50.0	10
12.5	40						

Preparation of Soluble Starch.

Purified potato starch is digested with HCl (Sp. Gr. 1·037) at 60°F. for seven days, stirring each day; 1 lb. starch and 1,000 cc. dilute acid in a two-litre bottle are convenient quantities. It is washed very thoroughly by decantation, at first with tap water, and afterwards with distilled water, until the washings are free from chloride and are neutral. It is

collected on a filter-paper in a Büchner funnel, sucked as dry as possible, and dried on a porous plate at 110°F. as rapidly as possible. When dry it is triturated in a mortar and rubbed through a fine hair sieve.

Starch solution. For the diastatic activity the starch is dissolved in boiling distilled water, and 2 grm. made up to 100 cc. It should be perfectly mobile (not gelatinous) indicating perfect conversion into soluble starch ; 10 cc. should not reduce more than 0·1 cc. of Fehling's solution.

The distilled water used in making up the starch solution must be pure and free from NH_3, HNO_2 (frequently present in commercial distilled water) which appreciably influence the diastatic conversion. (An alkalinity = 1 cc. $N/10$ acid per litre lowers the diastatic activity by 4°.)

Cold Water Extract

25 grm. of ground malt are digested with 250 cc. of distilled water containing 20 cc. of $N/10$ ammonia for three hours at 70°F., stirring 3 or 4 times during this period. After filtering, the Sp. Gr. of the bright filtrate is taken at 60°/60°F. The excess of the Sp. Gr. over that of water (= 1000) divided by 3·86 and multiplied by 10, gives the cold water extract per cent.

The percentage of ready-formed soluble carbohydrates may be ascertained approximately by subtracting 4 from the value obtained for the cold water extract (C.W.E.) per cent.

Sp. Gr. of 10 per cent. C.W.E.	C.W.E. per cent.	Sp. Gr. of 10 per cent. C.W.E.	C.W.E. per cent.	Sp. Gr. of 10 per cent. C.W.E.	C.W.E. per cent.
1005.0	12.9	1007.3	18.9	1009.5	24.6
.1	13.2	.4	19.1	.6	24.8
.2	13.4	.5	19.4	.7	25.1
.3	13.7	.6	19.6	.8	25.3
.4	14.0	.7	19.9	.9	25.6
.5	14.2	.8	20.2	1010.0	25.9
.6	14.5	.9	20.4	.1	26.1
.7	14.7	1008.0	20.7	.2	26.4
.8	15.0	.1	20.8	.3	26.6
.9	15.2	.2	21.2	.4	26.9
1006.0	15.5	.3	21.5	.5	27.2
.1	15.8	.4	21.7	.6	27.4
.2	16.0	.5	22.0	.7	27.6
.3	16.3	.6	22.2	.8	28.0
.4	16.5	.7	22.5	.9	28.2
.5	16.8	.8	22.8	1011.0	28.5
.6	17.1	.9	23.0	.1	28.7
.7	17.3	1009.0	23.3	.2	29.0
.8	17.6	.1	23.5	.3	29.2
.9	17.8	.2	23.8	.4	29.5
1007.0	18.1	.3	24.0	.5	29.7
.1	18.3	.4	24.3	.6	30.0
.2	18.6				

Statement of Results.

The results are expressed to the nearest first decimal place only, except in the cases of diastatic activity, which is recorded to the nearest integer, and are stated according to the following scheme :—

Extract in brewers' lbs. per standard quarter
Moisture, per cent.
Diastatic activity (Lintner value).
Tint (10 per cent. wort, 1 in. cell, " 52 " series Lovibond).
Cold water extract, per cent.
Ready-formed soluble carbohydrates, per cent

COLOURED MALTS.

As in the case of pale malts, the " Seck " or " Boby " mills (set at 0·5 mm.) should be used in the analysis of brown and crystal malts.

With black barleys and malts the character of the grind is not of such importance, for the extract of a black barley or malt is the same whether ground at seck 0·5 mm. or more finely in another type of mill. The use of a coffee mill, set close so as to obtain a fine grind, is recommended for grinding a black barley or malt.

Black malts and barleys, and brown and crystal malts are not commonly purchased on the basis of the standard quarter of 336 lb., various weights and measures being employed. For convenience of comparison, however, it is recommended that analytical results relating to such malts and barleys should be expressed in terms of pounds per excise standard quarter of 336 lbs.

Brown and Crystal Malts.

Extract. 50 grm. of the ground sample (seck 0·5 mm.) is mashed with 300 cc. of distilled water at 158°F., and when constant at 150°F., 100 cc. of cold water extract of malt previously heated to 150°F. is added. The mixture is kept at 150°F. for 1 hour, cooled to 60°F., diluted to 515 cc., shaken, filtered, and the Sp. Gr. taken. The necessary correction for the cold water extract of malt employed is obtained by diluting 100 cc. of the malt extract with 300 cc. of water, the mixture being kept at 150°F. for 1 hour, subsequently cooled (60°F.), made up to 500 cc., filtered, and its Sp. Gr. taken.

Sp. Gr. of mash – Sp. Gr. of C.W. extract of malt
  = Sp. Gr. due to malt alone.
Extract of brown, etc., malt
  = Sp. Gr. due to malt × 3·36 brewers' lbs. per
    quarter of 336 lbs.

Cold Water Extract of Malt. The extract is prepared from a well modified pale malt of diastatic power 30°–40° (Lintner) by digestion with 3 times its weight of distilled water for 1 hour at 60°–70° F. and subsequent filtration.

Colour. 20 cc. of the above extract is diluted to 100 cc. and the colour read in a 1 in. cell. The colour due to the malt extract is neglected.

Black Barleys and Malts.

Extract. 50 grm. of the ground sample (coffee mill used) is extracted with about 350 cc. boiling distilled water, stirring well to prevent balling. The infusion is kept in a boiling water-bath for 1 hour, after which it is cooled, diluted to 515 cc. (60° F.), shaken, filtered through an open-textured filter paper, and the Sp. Gr. of the filtrate taken.

Extract = Sp. Gr. × 3·36 brewer's lbs. per quarter.

Colour. 20 cc. of the filtrate, which must be brilliant, is diluted to 1000 cc., and the colour read in a 1 in. cell.

Caramel.

Colour. 10 grm. is dissolved in water and diluted to 100 cc. 10 cc. of this solution is diluted to 1000 cc., filtered if necessary, and the colour read in a 1 in. cell.

STATEMENT OF RESULTS.

The results are expressed to nearest first decimal only, except in the case of tint, which is recorded to the nearest half unit.

Brown and Crystal Malts.
Extract per standard quarter of 336 lbs.
Colour. In 1 in. cell. "52" series, Lovibond (2 per cent. extract).

Black Barleys and Malts.
Extract per standard quarter of 336 lbs.
Colour. 1 in. cell. "52" series, Lovibond (0·2 per cent. extract).

Caramel.
Colour. 1 in. cell. "52" series, Lovibond (0·1 per cent. solution).

(In commercial practice many caramels have their colour expressed *on the caramel.* This figure is obtained by multiplying the colour of the 0·1 per cent. solution by 1000.)

Time of Saccharification

In addition to the "Committee" determinations, a commercial statement of the analysis of a sample of malt very often contains a figure known as the "Time of Saccharification."

10 grm. of ground malt is mashed with 100 cc. water at 155°F., and maintained at 150°F. After 10 minutes the mixture is stirred and allowed to settle somewhat. Several cc. of the wort are withdrawn and tested with iodine solution for starch, this being repeated every 5 minutes until conversion of the starch is complete. It frequently happens that starch nearly disappears after, for example, 30 minutes, but that a small quantity persistently remains for a considerable time longer.

The following determinations, though not included in a commercial analysis, are sometimes required.

"Dry Extract."

100 cc. of a solution containing 1 grm. dry malt extract weighs 100·40 grm., i.e., 1 grm. malt extract weighs 0·4 grm. when in solution.

Hence dry weight of malt extract in 100 cc. = (weight of 100 cc. − 100)/0·4 = 10 grm. malt.

and dry weight of extract from 1 quarter malt (336 lbs.)
= (weight of 1,000 cc. − 1,000)/0·4 × 3·36.
= ordinary brewers' extract/0·4,
= brewers' extract × 2·5.

Calculation of "Grains."

1 quarter malt with x per cent. water = 336 − 3·36 x dry solids.
Dry weight of extract from 1 quarter = y
Hence weight of dry "grains" from 1 quarter malt (336 lbs.)
= (336 − 3·36 x) − y.

Non-Coagulable Proteins.

25 grm. ground malt is digested with 250 cc. distilled water at 60°F. for 3 hours, stirring occasionally, the mash is filtered bright and 100 cc. boiled for 20 minutes, again made up to 100 cc., filtered, and 10 cc. (= 1 grm. malt) of filtrate taken for a Kjeldahl determination, using 10 cc. acid and 5 grm. $KHSO_4$.

$$N \times 6·3 = \text{non-coagulable protein.}$$

As some analysts use the factor 6·25, it is advisable to state the factor used in a statement of results.

Malt Worts.

For analysis of malt worts see under "Wort Analysis."

PHYSICAL EXAMINATION.

The chemical examination must be supplemented by a careful physical examination, noting :—

1. The extent of acrospire growth. This should be $\frac{2}{3}$ to $\frac{3}{4}$ the length of the corn, and the more uniform the better the sample.

2. The presence or absence of mould.

3. The presence of damaged or half corns.

4. Any corns attacked by weevil.

5. "Brightness." The brightest malts are sometimes those worst prepared. Malts from kiln-dried barleys are usually of poorer colour than those made direct. Thorough withering generally means loss of colour.

6. Flavour. Sweet tasting malts are suspicious. Under-cured malts have a "pasty" flavour and also a peculiar bitterness, detected only after thorough mastication.

7. The appearance of sections cut in the farinator. Well modified corns have a mealy, and hard corns a vitreous appearance.

INTERPRETATION OF RESULTS.

1. *Moisture* may be as low as 0·5 when malt is fresh from the kiln, but rapidly increases to 1·5 per cent., and in a properly stored malt will not exceed 2·5—3 per cent. A malt with excess of water (say over 3 per cent.) is said to be "slack," and if the moisture is above 3·5 per cent. certainly requires re-drying before use, although re-drying does not entirely recover a malt which has once become "slack." Contracts generally specify delivery at brewery at a maximum of 3 per cent. This means leaving the malting at a maximum of 2·5 per cent., as the average moisture absorbed in transit is 0·5 to 0·7 per cent.

2. *Extract.* This figure is a measure of the amount of beer the brewer can produce from the malt, and naturally the higher this figure the better. However, it must be remembered that both a poor quality malt and a high quality malt may both yield equally high extracts, but the quality of such extracts will be decidedly different. The quality of the extract is determined partly by the remaining analytical data, partly by the physical examination and the district in which the barley was grown. Malts from foreign barley usually give 3–4 per cent. less extract than those from English barley.

3. *Tint.* It is generally not desirable to use a malt paler than 3·5° (on 10 per cent. wort), as a danger from under-curing then becomes probable; but even for pale beers it is

not necessary to use a malt paler than 4°. High tints point to higher temperatures on the kiln and the possibility of further crippled diastase.

4. *Cold water extract* (C.W.E.), *soluble non-coagulable protein*, and *ready-formed sugars* (R.F.S.).

These figures are a guide as to whether the malt has been forced, and it is generally agreed that high C.W.E. indicates defective manufacture. Forced malts produce a wort with excess of assimilable nitrogen, which gives a " thin " beer of low stability. The C.W.E. indirectly indicates the amount of non-coagulable nitrogen, and this is proportional to the assimilable nitrogen. Briant gives the maximum soluble non coagulable protein as 2·6 per cent. H. Brown states that there is no increase of assimilable nitrogen during drying on the kiln, but that the R.F.S. rise considerably at this stage. Briant has drawn attention to exceptions.

5. *Diastatic activity.* The following are intended as guides and not rigorous standards :

Mild and black beers. The malt should have D.A. 24°–32°.
Pale ales. D.A. 32°–42°.

6. *Time of Saccharification* (T.S.).

This figure has lost favour somewhat, owing to the indefinite end-point with iodine under the conditions of the test.

Briant gives the following as a guide :

i. Extremely well modified malts   T.S. = 25 minutes or less.
ii. Average modification   T.S. = 25–35 minutes.
iii. Poor   „   T.S. = 45   „
iv. Bad   „   T.S. = over 45   „

The test in its present form is not suitable for including in a malt analysis, but many commercial analyses include this figure, although not recommended by the Malt Analysis Committee.

SPECIMEN ANALYSES OF MALT.

	Californian. 1st Qual.	Californian. 2nd Qual.	Chilian	Ouchac	Australian Chevalier	English Pale Ale Malt	English Mild Ale Malt. 1st Qual.	English Mild Ale Malt. 2nd Qual.
	1922	1922	1921	1913	1920	1922	1922	1922
Moisture %	1.2	1.5	1.6	2.7	2.9	1.6	1.2	1.6
Extract	92.4	90.7	91.9	91.5	93.7	98.4	97.8	94.4
Colour (10% wort)	4.5	4.5	4.0	5.0	5.5	4.5	8.0	8.0
C.W.E. %	18.8	19.9	19.8	19.1	19.0	19.9	20.6	19.6
R.F.S. %	14.8	15.9	16·1	15.1	15.0	15.9	16.6	15.6
D.A.	34	34	40	44	33	37	36	36

3. Flaked Maize or Rice.

Determinations required are the brewing extract, moisture, and oil, and occasionally proteins (= N × 6·3 or 6·25), and starch. See "Carbohydrates."

Extract. For this determination a cold water extract of malt is necessary, which is prepared as follows :

A tender, well-modified malt of D.P. > 30° is extracted with three times its weight of distilled water for one hour at 60°–70° F. and subsequently filtered.

20 grm. flaked material is mixed with 120 cc. distilled water and the temperature adjusted to 160° F. 50 cc. of the above cold water extract are then added, the mixture well stirred, covered with a watch glass and kept at 150° F. for two hours, after which the whole mash is washed through a large funnel into a 200 cc. flask, cooled to 60° F., and diluted to the mark. The flask is well shaken, the contents filtered through a dry filter paper, and the Sp. Gr. of the filtrate determined with Sp. Gr. bottle or Sprengel tube.

50 cc. of cold water extract is treated exactly as the above, omitting the flakes. After two hours the extract is washed into a 200 cc. flask, cooled, diluted to the mark, filtered through dry filter paper, and the Sp. Gr. of the filtrate taken.

Sp. Gr. of maize extract and cold water extract = x
,, ,, cold water extract = y
,, ,, maize extract = $x - y$

Extract in brewer's lbs. from 336 lbs. maize = $(x - y)$ 3·32.

($3·32 = 3·36 \times \dfrac{200}{202·5}$ is used, as it is necessary to allow 2·5 cc. for the volume occupied by the cellulose, etc.)

Moisture. 5 grm. are dried for 5 hours in a boiling water oven. The loss of weight is taken as moisture.

Oil is determined by extracting the flaked material with ether for six hours, after soaking overnight, in a Soxhlet apparatus.

INTERPRETATION OF ANALYSIS OF FLAKED MATERIALS.

Immediately on manufacture the moisture is reduced to 4 per cent., but rapidly rises, and is seldom below 6 per cent. on delivery at the brewery.

	Maize Flakes. per cent.	Rice Flakes. per cent.
Starch	>75	>80
Fat	< 1.3	< 0.5
Proteins	<10	< 8.5
Moisture	< 8	< 8

Flaked oats give an average extract of 88·5 brewer's lbs. per quarter.

Malted oats give an average extract of 70—76 brewer's lbs. per quarter.

Composition of Flaked Grains (L. Briant).

	Rice.	Maize.	Barley.
Starch	81.63	76.40	72.31
Oil	0.20	1.30	1.72
Proteins	8.73	9.82	10.35
Ash	0.37	0.45	2.35
Moisture	7.90	7.50	5.82
Cellulose	1.17	4.53	7.45
	100.00	100.00	100.00

4. Raw Grain.

This includes maize grits, rice grits, barley.

Extract. 20 grm. of the well-ground sample are brought into a beaker, and 110 cc. cold water added together with 5 cc. of cold water extract of malt (prepared as under "Flaked grain"). The beaker and contents are slowly heated up to boiling point in a water-bath to gelatinise the starch. During this time the contents must be continually stirred; the boiling is continued for one hour, after which the contents are cooled to 160°F., and 45 cc. of the cold water extract added (giving a total of 50 cc.). The whole is allowed to stand 2 hours at 150°, and then cooled to 60°F., washed into a 200 cc. flask and diluted to the mark. The Sp. Gr. of the clear filtrate is taken = S_1.

The cold water extract correction is determined by digesting 50 cc. with 100 cc. water by the side of the above for 2 hours at 150°F., making up to 200 at 60°F., and taking the Sp. Gr. of the clear filtrate = S_2.

Brewers' extract in lbs. (brewers) per 336 lbs. of grits
$$= 3·32 \times (S_1 - S_2).$$

Oil is determined as under "Flaked grain."

Moisture is determined by drying 5 grm. for 5 hours in the hot-water oven.

Mineral matter, if necessary, by careful ignition in Pt dish, finally igniting more strongly to a white ash.

Proteins. By Kjeldahl. N × 6·25 or 6·3.

Composition of Maize and Rice Grits (Briant).

	Maize Grits.	Rice Grits.	Barley.
Oil	$< 1\%$	$< 0.4\%$	$< 2.5\%$
Water	$<14\%$	$<14\%$	
Extract	96—100	103	88
Starch	74%	79%	
Proteins	8%	$< 7.5\%$	$<12.5\%$

	Maize Grits.	Rice Grits.
Starch	73.80	79.19
Oil	0.82	0.80
Proteins	9.05	8.91
Ash	0.40	0.30
Moisture	10.85	10.30
Cellulose, etc.	5.08	0.50

5. Malt Extract.

1. *Free Maltose.*

The copper oxide from 20 cc. of a 2 per cent. solution is determined by the Brown, Morris and Millar method as under " Sugars."

250 cc. 10 per cent. solution + 2 grm. of washed pressed yeast are allowed to ferment at about 26° C. until fermentation is complete (usually not less than 48 hours), after which the solution is heated to boiling for about half an hour on the water-bath to remove alcohol; a small amount of alumina cream is added to aid clarification, and the whole made up to 250 cc. again and filtered. The Cu reducing power is determined on a suitable quantity, say 20 cc., but this requires trial, and the maltose obtained from the CuO on reference to the table.

Maltose before fermentation − maltose after fermentation = maltose present in the free condition and as very low type maltodextrins (*i.e.* rich in maltose).

2. *Maltose present as maltodextrins.*

This is given by the maltose found after fermentation, as in (1), but must previously be corrected for the CuO determined under (4) below.

3. *Dextrin present as maltodextrins.*

To 200 cc. of the fermented solution from (1) is added 10 cc. of malt extract (prepared by soaking 400 grm. of ground malt with 1000 cc. distilled water at about 15·5° C. (60° F.), containing 5 cc. of chloroform, for at least 5 hours, straining off the malt and filtering bright; this will keep for about 14 days in a stoppered bottle without decomposing; it must be rejected on turbidity appearing), and the mixture digested at 55° C. (131° F.) for 1 hour. Maltodextrins are converted into free maltose.

The correction for the malt extract is determined by adding 5 cc. to 100 cc. water and treating as above.

The two solutions are heated to boiling for about half an hour and diluted to 200 cc. and 100 cc. respectively. The Cu reduction is determined on suitable quantities of the filtrates, say 10 cc., and the maltose equivalent to each determined from the table.

Maltose in converted solution − maltose due to malt extract − maltose before conversion, found in (2) = maltose produced by diastase in the malt extract from the dextrin of the maltodextrin.

$$\text{Dextrin} = \text{maltose} \times \frac{180}{198}$$

4. *Stable dextrin.*

150 cc. of the degraded conversion from (3) are fermented with about 1·5 grm. of washed pressed yeast at 26° C. (79°F.) for about 48—72 hours, after which the solution is heated at the boil for about half an hour to expel alcohol, cooled, and made up to 150 cc. The solution is filtered and the polarimeter reading taken (in circular degrees).

100 cc. of this fermented solution are completely fermented with 5 cc. of malt extract and 1 grm. of pressed yeast at 26°C. (79° F.).

A " blank " is carried out on 100 cc. water, 5 cc. malt extract, and 1 grm. yeast. In presence of diastase (in the malt extract) the stable dextrin is fermented away by the yeast, although neither agent alone is capable of attacking this dextrin.

The fermented conversion and the blank after fermentation are both kept at boiling point for about half an hour to expel the alcohol, cooled, and both are made up to 100 cc., using a small amount of alumina cream for clarification. The optical rotations and Cu reductions are determined on the filtrates.

The rotation of the blank is deducted from that of the actual test and the stable dextrin calculated from the loss of rotation on fermentation with diastase and yeast.

Rotation in 2 dm. tube before fermentation with
diastase and yeast   = x

Rotation in 2 dm. tube after fermentation with
diastase and yeast   = y

Rotation of blank in 2 dm. tube after fermentation
with diastase and yeast   = z

Loss in rotation = $x - (y - z)$.

1 grm. dextrin in 100 cc. solution gives a reading of a in 2 dm. tube.

$$202 = \frac{a \times 100}{2 \times 1} \qquad a = \frac{202}{100} \times 2 = 4\cdot04.$$

Stable dextrin in 100 cc. of solution = $x - (y - z) / 4\cdot04$ from which the percentage in the malt extract is calculated.

The CuO due to the fermented conversion *less* that due to the cold water extract of malt ("diastase") used is required for making the correction in (2).

5. *Diastatic activity.*

Some malt extracts contain no diastase as it has been killed in their preparation; others, however, contain diastase and are then known as diastatic malt extracts; in these latter the D.A. is determined exactly as under malt analysis, but generally the D.A. is very high, therefore less of the extract must be allowed to act on the starch solution.

6. *Protein.*

Determined by the Kjeldahl method as under "Malt analysis."

7. *Moisture.*

The excess specific gravity of a 10 per cent. solution over 1000 is divided by 4·0, which gives total solids in 100 cc.; this multiplied by 10 gives the apparent total solids percentage. This figure should be corrected for the ash as under "Moisture in Sugar," to give the real total solids percentage.

Moisture percentage = 100 − real total solids percentage.

8. *Ash.*

By careful ignition of about 5 grm. in a platinum dish.

A. R. Ling (*Analyst*, 1904. **29**, 244) has pointed out that dextrose is present in genuine malt extract; this sugar is determined as glucosazone and the necessary corrections made in the figures obtained in the foregoing determinations.

SPECIMEN ANALYSES OF MALT EXTRACTS (A. R. Ling).

	I.	II.	III.	IV.	V.	VI.
Sp. gr. 15.5/15.5°	1395.70	1395.12	—	—	1408.43	1377.82
	%	%	%	%	%	%
Maltose (apparent)	31.1	30.9	24.8	27.4	34.2	25.2
Dextrose	17.2	18 2	22.0	19.1	12.5	20.0
Dextrin (apparent)	9.8	8.6	10.0	9.8	9.9	6.7
Unfermentable matter (as dextrin)	4.5	3.5	8.9	5.8	—	—
Ash	1.45	1.49	1.58	1.64	1.34	1.64
Water	24.30	24.67	27.36	24.84	24.38	29.52
Diastatic activity	30.8	27.2	32.3	25.6	39.2	46.5
S.R.P. $[a]_D$	91.8	90.5	84.2	86.8	94.5	81.1

When the total copper reduced, less that due to dextrose, is calculated to maltose, the "apparent maltose" is obtained. The total polarimetric reading less that due to "apparent maltose" and dextrose gives the "apparent dextrin."

6. Caramel.

1. *Colouring power.*

This is determined by the standard method of "The Institute of Brewing Committee on Coloured Malts and Caramel, 1910," given under "Malt analysis."

2. *Loss of colour on fermentation.*

25 cc. of 10 per cent. caramel solution + 25 cc. wort or malt extract (Sp. Gr. about 1050—1060) are fermented with 1 grm. washed, pressed yeast at 26°C. for 48—72 hours, after which the whole is made up to 100 cc. and filtered. 10 cc. of the filtrate are diluted to 250 cc. and the colour read in a 1 in. or $\frac{1}{2}$ in. cell as necessary. A correction can be made for the colour of the wort if desired, but never amounts to more than 1 unit, unless a very dark wort is employed, which is quite unnecessary, and is usually only 0·5. This reading is taken on the same strength solution as in (1), so that the difference gives the loss and is calculated to a percentage.

3. *Brewers' extract* per 2 cwt.

The Sp. Gr. of a 10 per cent. solution is taken and the excess over 1000 multiplied by 2·24.

4. *Fermentable matter.*

The Sp. Gr. of a 10 per cent. solution is taken. 125 cc. are fermented with 1–2 grm. well washed, pressed yeast for 48–72 hours at 26°C., after which the solution is made up to 250 cc., filtered to remove all yeast and 200 cc. evaporated down on the water-bath to about 70 cc. to remove alcohol, and washed into a 100 cc. flask and diluted to the mark. This solution will be equivalent to an original 10 per cent. solution, and on this solution the Sp. Gr. is taken, the loss of Sp. Gr. calculated to an original excess Sp. Gr. over 1000 of 100 gives the fermentable matter per cent.

5. *Proteins.*

By the usual Kjeldahl method, using 4–5 grm. caramel.

6. *Ash.*

By careful ignition of 4–5 grm. caramel in platinum dish.

7. *Moisture.*

By the method given under "Moisture in Sugar," making the usual correction for ash. The solution factor 3·86 is used.

8. *Action on bright beer.*

Bright beer is tinged to a deep tint with the sample, and the presence or absence of cloudiness or precipitate is observed both immediately and after standing a day or two.

INTERPRETATION OF CARAMEL ANALYSIS.

Caramels are prepared either from starch sugar (glucose) or from cane sugar; those from the latter probably give a richer flavour.

1. *Colour.* This varies considerably.

2. *Loss of colour on fermentation.* Some caramels show distinct loss, but good samples generally lose less than 4 per cent.

3. *Brewers' extract.* This is generally lower the higher the colour, but caramels of equal colour can show varying extracts, of which the higher is favoured by the brewer.

4. *Fermentable matter.* Most caramels show some fermentable matter, but an excessive amount shows imperfect preparation, undecomposed sugar remaining at the expense of colour.

5. *Protein.* To some extent this indicates the purity of the raw material used for preparation of the caramel; however, it must be remembered that 0·5 per cent. of sodium or ammonium carbonate is sometimes added to intensify the colour. Free NH_3 or ammonium salts may be estimated by distillation with magnesia.

6. *Ash.* This also is some indication of purity of raw products, but if sodium carbonate has been used it will increase the ash.

7. *Moisture.* Liquid caramels frequently contain between 20–30 per cent. moisture.

8. *Action on bright beer.* Low grade caramels produce a cloud and precipitate when added to bright beer, the latter containing some of the colour, so that loss of colour results; but, apart from this, no caramel can be passed as satisfactory if it produces such cloud or precipitate.

The flavour is very important and is conveniently noted on the 10 per cent. solution. Some caramels have bitter flavours, but richness is generally associated with low colour. Particles of insoluble carbon are objectionable only in so far as they mean colour lost.

Caramels sometimes have a trace of liquorice added, especially those for black beers. A caramel should show neither very acid nor alkaline reaction.

SPECIMEN ANALYSES OF CARAMELS (F. Robinson).

	Beer.	Caramel for		Stout.
		Stout.	Beer.	
Colour	31000	17000	33000	26000
Loss of colour on fermentation	0%	0%	3%	0%
Brewers' extract per 224 lbs.	62.4	67.3	65.5	62.9
Fermentable matter	20.1%	24.7%	14.3%	16.5%
Protein	2.18%	1.92%	1.41%	1.82%
Ash	3.0%	2.18%	3.34%	2.80%
Moisture	30.8%	24.4%	27.6%	30.1%
Flavour	v slightly bitter	sweet	slightly sweet	pleasant
Beer, cloud	nil	nil	v. slight	nil
precipitate	small, pale	v. small	fair, pale	v. small

7. Hops.

Analysis does not as yet play a very important part in the valuation and use of hops, the chief method by which they are valued being the personal. The following determinations may be made :

1. *Moisture.*

Determined on 3-5 grm. by drying in boiling water oven for 5 hours. Some or all of the essential oil is also removed, but it does not exceed 0·5 per cent., so that the error is not very great, and the results are sufficient for technical requirements.

Drying over sulphuric acid *in vacuo* is preferable.

2. *Resins.*

These have been separated into three substances :

α-Resin or humulone. ⎫ = Soft resins (soluble in
β-Resin or lupulinic acid. ⎬   petroleum ether).
γ-Resin.   = Hard resin (insoluble in petroleum ether).

Soft resins. Determined by extracting about 3–4 grm. hops with petroleum ether, b.pt. 125—130° F., for about 24 hours in a Soxhlet apparatus and drying the extracted resins to constant weight in the hot water oven.

Hard resin. After extraction with petroleum spirit, as above, to remove soft resins, the hops are extracted with ether for about 12 hours. The extracted hard resin is dried to constant weight in hot water oven.

3. *Foreign matter.*

Determined by carefully picking out from a 50 grm. sample and weighing. The resins are determined on the whole hop flower so that foreign matter has to be considered together with resin in valuing the hops.

4. *Sulphur.*

This is introduced in one of two ways :—

    i. The growing hop is sprayed with finely-divided sulphur to prevent mould.

    ii. The hops are treated with sulphur during kilning when sulphur dioxide is formed and taken up by the hops.

1. To detect free sulphur. 5 grm. hops are boiled with 250 cc. water and 5 grm. pure slaked lime for 20 minutes. The liquid is cooled, filtered and tested immediately with dilute sodium nitroprusside solution. Red colour indicates sulphide, and hence free sulphur in the hops. The colour reaction may be made quantitative.

ii. To detect sulphur dioxide. The hops are treated with Zn and HCl. Any sulphur dioxide is converted into hydrogen sulphide and is passed into lead acetate solution. The PbS precipitated may be determined gravimetrically.

(5) *Tannin.* Originally tannin was considered to be of value in precipitating the proteins of the wort and its percentage decreased with increase in age of the hop. A. C. Chapman, using his cinchonine method of estimation (*Journ. Inst. Brew.,* 1907, p. 646, and 1909, p. 360), has shown that the tannin percentage gives no valuable information of the brewing quality of the hop. Briant and Meacham hold the same opinion.

On the Valuation of the Antiseptic Properties of Hops the following papers may be consulted :—

A. Brown and G. Ward (*Journ. Inst. Brew.,* p. 641, 1910).
A. Brown and D. Clubb (*Journ. Inst. Brew.,* p. 261, 1913).

RESULTS OF ANALYSIS OF HOPS.

Moisture. The amount should not exceed 10 per cent., or the hop will not keep well on storage. 8-9 per cent. is preferable.

Sulphur. Many brewers have great objection to sulphured hops because it disguises their real character; on the other hand, a sulphured hop generally keeps better than an unsulphured one, and the practice has not definitely been proved to be injurious. It is said that when sulphur is

sprinkled after the flower has developed it produces a peculiar smell in the dried hop which is strongly objected to, and yeast difficulties have with good reason been ascribed to heavily sulphured hops. Sulphur treatment in kilning is rarely practised abroad, but is very general in this country.

Resins. The soft resins are generally valued as preservatives, but hard resin is said to have no such action. As the hops are stored, the soft resins diminish and the hard resin increases; these changes are hastened by high temperature and high moisture content, chiefly by the former. Below 40°F. hops may be stored for a year with very little change in the resin values.

Briant gives the following analyses :

Growth of Hops.	Hard Resins. Per cent.	Soft Resins. Per cent.
East Kent	3.91	10.65
Sussex	5.30	9.12
Worcester	5.12	7.60
Goldings	4.25	11.23
Californian	8.45	12.20
Bavarian	8.20	11.30
British Columbian	8.55	12.30
Hallertauer	7.60	11.90

WORT AND BEER.

F. Robinson, M.Sc.Tech., B.Sc., F.I.C.

Analysis of Malt Wort.

I. Malt Wort.

This is prepared in a similar way to the hot water extract under malt analysis. The analysis generally aims at determining the result of the digestion of the starch; however, the fact that malt yields to cold water bodies showing reducing power and optical activity makes correction for these necessary.

A 10 per cent. cold water extract is first prepared by extracting 25 grm. of the ground sample with 250 cc. water at 60°C. for 3 hours. The following determinations are made on the bright filtrate :

1. Ready-formed sugars. (See " Malt analysis.")
2. Copper reducing power on 20 cc. by Brown, Morris and Millar's method. (See " Sugar analysis.")
3. Optical rotation.

A 10 per cent. hot water mash is prepared as under " Malt analysis." The bright filtrate (wort) is used for the following determinations :

1. Sp. Gr., excess of which over $1000 \div 3.86 =$ solids in 100 cc. (Some analysts use the factor 4·0.)
2. Copper reducing power on 20 cc.
3. Optical rotation.
   (Decolorisation may be necessary ; to 50 cc. wort are added a few drops of lead basic acetate solution and alumina cream, diluted to 100 cc. and filtered bright. The rotation is multiplied by 2 to correct for dilution).
4. Protein by Kjeldahl.
5. Ash by ignition.

The maltose is obtained from the CuO values by the table, and the maltose in hot water extract is corrected for the sugars calculated as maltose in the cold water extract. From this the maltose in 100 cc. wort due to starch conversion is found $= M$.

If M grm. maltose in 100 cc. solution read in a 2 dm. tube give a rotation of a :

$$138 = \frac{a \times 100}{2 \times M} ; \qquad a = \frac{138\ M \times 2}{100} = 2 \times 1.38\ M$$

The optical rotation in a 2 dm. tube of the hot extract (wort) is corrected for that due to the cold extract, and from the result (R) the reading due to maltose is deducted, giving : The reading due to dextrin in 2 dm. tube $= R - (2 \times 1.38\ M)$.

If 1 per cent. dextrin solution in 2 dm. tube gives a reading of A :

$$202 = \frac{A \times 100}{2 \times 1} ; \qquad A = \frac{202 \times 2}{100} = 4.04$$

Grams dextrin in 100 cc. wort $= \dfrac{R - (2 \times 1.38\ M)}{4.04.}$

The total solids in 100 cc. wort having been determined, the maltose and dextrin are calculated to a percentage on the *dry solids* (not on the malt), so also are the other figures if their statement is necessary. By this means the composition of wort of different Sp. Gr. (*i.e.*, concentrations) can be compared.

The above method of analysis is similar to that proposed by Heron, but it ignores the malto-dextrins, which certainly play an important part in brewing.

Determination of Malto-dextrins and Stable Dextrin.

These are determined by the method of Moritz and Morris, described in full under " Malt extracts."

The method may be somewhat shortened if stable dextrin is not required.

Determination of Malto-dextrins only

The following example given applies to a wort of Sp. Gr. about 1030.

The following determinations are made :

i. Copper reduction on 10 cc. of 20 per cent. wort, prepared by diluting 20 cc. of that at Sp. Gr. 1030 to 100 cc.

ii. 25 cc. wort + 2·5 cc. diastase solution (*i.e.*, cold water extract of malt prepared as under " Malt Extracts ") are kept at 130°F. for 1 hour, cooled and diluted to 100 cc. The copper reduction on 10 cc. is determined. The CuO reduction for the diastase solution must be known, and the necessary correction made.

iii. 50 cc. wort, after boiling to sterilise, is fermented with about 0·2 grm. washed, pressed yeast at 80°F. for 48 hours; alumina cream is added, and the mixture made up to 100 cc., filtered, and the copper reduction taken on 25 cc.

iv. 50 cc. of boiled wort + 0·25 cc. diastase solution + 0·2 grm. yeast is allowed to ferment 48 hours at 80°F. In presence of diastase the yeast ferments away malto-dextrins and stable dextrin. Alumina cream is added to the fermented liquid, which is diluted to 100 cc., filtered, and the reducing power taken on 25 cc. of the filtrate. This gives the correction to be applied to (iii) before the combined maltose can be calculated. It will be seen that CuO due to the diastase solution is included in the correction, but the amount is negligible.

Maltose in malto-dextrin in 25 cc. wort = 2[(iii) − (iv)].
Dextrin in malto-dextrin in 25 cc. wort.

$$= 0.95 \left\{ 10 \text{ (ii, corrected for diastase)} - 12.5 \text{ (i)} \right\}$$

The figures (i)—(iv) represent quantities of *maltose* as determined under these headings from the CuO and maltose table.

D/M gives the malto-dextrin " type " or " ratio."

The malto-dextrin is calculated to a percentage of the dry solids in solution.

II. Copper Wort.

This is the wort from the mash tun which is running into the boiling copper. The sample should always be taken after the same interval (generally 20 minutes) from the time of starting to run off the wort from the mash tun. The wort is boiled *immediately* to kill diastase and so prevent any further alteration in the starch conversion products.

The analysis is made either by Heron's method, as under " malt wort," when the corrections for cold water extract are required, or the wort is examined for malto-dextrins and stable dextrin by Moritz and Morris' method, in which corrections for cold water soluble bodies are not required. Moritz and Morris' method gives the most useful information.

The optical activity of the wort is frequently taken, and the specific rotatory power calculated on the dry solids as follows :

$$S.R.P. = \frac{\alpha \times 100}{l \times c}$$

α = optical rotation,

l = length of observation tube in dm.

c = concentration (grm. per 100 cc.) = excess Sp. Gr. over 1000 ÷ 3·86 (or 4·0, according to different authorities).

It is a useful guide in a series of mashings with the same composition of grist (malts, etc.).

INTERPRETATION OF RESULTS.

Morris and Moritz give the following table of malto-dextrin types for the various worts of typical ales :

	Family Bitter.	Stock Bitter.	Mild Running Ale.	Stout.	Pale Ale.
Gravity	1052.8	1066.7	1050	1075	
Maltose in maltodextrin	4.19	3.75	4.70	10.00	
Dextrin ,, ,,	7.24	7.44	4.66	8.30	
Total maltodextrin per cent. of solids	11.43	11.19	9.36	18.30	
Type	1 M. 1.7 D	1 M. 2 D.	1 M. 1 D.	1 M. 1 D.	1 M. 2 D.

The following is an example of a wort analysis according to Heron's method :—

Substance.	% of Wort Solids.
Maltose	48.62
Dextrin	19.65
Protein	4.80
Ash	1.65
Ready formed sugars	23.08
Other substances	2.2
	100

For a full discussion of the influence of the type of malto-dextrins, which is very great and finds no indication in Heron's method, Moritz and Morris, "The Science of Brewing," may be consulted.

A point to note is that a beer does not contain the same type maltodextrin as the wort from which it was produced ; for example, a pale ale wort gave a type $\left\{ \begin{array}{l} 1 \text{ M} \\ 2 \text{ D} \end{array} \right.$, but the beer gave $\left\{ \begin{array}{l} 1 \text{ M} \\ 1 \text{ D} \end{array} \right.$ (analysed immediately on "racking," *i.e.* filling into casks) ; during storage of the beer the type is still further lowered, and the (low type) maltodextrin destroyed by fermentation by the yeast.

Analysis of Beer.

1. *Original gravity* (O.G.).

(a) Distillation method.

The original gravity of a beer may be described as the specific gravity of the wort, before fermentation, from which the beer was made.

For excise purposes this is determined by the distillation process, using the recent new tables of Sir T. E. Thorpe and H. T. Brown.

The sample of beer is filtered through a dry filter into dry beaker, keeping the filter covered with a clock glass. The distillation apparatus consists of a large flask connected by a wide leading tube (which slopes down towards the flask) with a vertical spiral condenser. Into the flask is measured 200 cc. of filtered beer, and distillation carried out until two-thirds of the liquid has passed over, collecting the distillate in a 200 cc. flask. After distillation the distillate is diluted to 200 cc., and its Sp. Gr. determined accurately.

1000 − Sp. Gr. = degrees spirit indication.

The residue in the distillation flask is also made up to 200 cc. again, and its Sp. Gr. accurately determined.

O.G. = residual gravity + gravity lost corresponding to spirit indication.

ORIGINAL GRAVITY TABLE, 1914 (T. E. Thorpe and H. T. Brown).

Spirit Indica- tion.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
			Corresponding Degrees of Gravity Lost.							
0	0.00	0.42	0.85	1.27	1.70	2.12	2.55	2.97	3.40	3.82
1	4.25	4.67	5.10	5.52	5.95	6.37	6.80	7.22	7.65	8.07
2	8.50	8.94	9.38	9.82	10.26	10.70	11.14	11.58	12.02	12.46
3	12.90	13.34	13.78	14.22	14.66	15.10	15.54	15.98	16.42	16.86
4	17.30	17.75	18.21	18.66	19.12	19.57	20.03	20.48	20.94	21.39
5	21.85	22.30	22.76	23.21	23.67	24.12	24.58	25.03	25.49	25.94
6	26.40	26.86	27.32	27.78	28.24	28.70	29.16	29.62	30.08	30.54
7	31.00	31.46	31.93	32.39	32.86	33.32	33.79	34.25	34.72	35.18
8	35.65	36.11	36.58	37.04	37.51	37.97	38.44	38.90	39.37	39.83
9	40.30	40.77	41.24	41.71	42.18	42.65	43.12	43.59	44.06	44.53
10	45.00	45.48	45.97	46.45	46.94	47.42	47.91	48.39	48.88	49.36
11	49.85	50.35	50.85	51.35	51.85	52.35	52.85	53.35	53.85	54.35
12	54.85	55.36	55.87	56.38	56.89	57.40	57.91	58.42	58.93	59.44
13	59.95	60.46	60.97	61.48	61.99	62.51	63.01	63.52	64.03	64.54
14	65.10	65.62	66.14	66.66	67.18	67.70	68.22	68.74	69.26	69.78
15	70.30	70.83	71.36	71.89	72.42	72.95	73.48	74.01	74.54	75.07
16	75.60	–	–	–	–	–	–	–	–	–

(b) Evaporation method.

The Sp. gr. of the original beer is ascertained, after agitation to remove CO_2 as far as possible. A measured portion of the sample is evaporated to drive off the alcohol, then made up to the original volume, and the Sp. gr. taken. The difference in the two gravities gives the spirit indication, which is corrected as before for any excess acidity. The corresponding gravity lost is given by the table of Thorpe and Brown; this figure requires correcting by the addition of 1/40th of its value.

This method may be used as a check on the distillation process by including in the latter a determination of the Sp. gr. of the beer before distilling.

If the beer has become sour the original gravity as just determined is incorrect, because some of the alcohol has been converted into acetic acid. In such a case the sample should be neutralised before distillation and allowance made for the acidity. The authorities assume that normal beer contains 0·10 acid expressed as acetic acid; therefore after determina-

D 2

tion of acidity a deduction of 0.10 per cent. is made before calculating the correction. The official method of determining the acidity is by titration of the sample with N/10 alkali; the end-point is ascertained by means of litmus paper. Previous to titration the sample should be boiled for 2 minutes to expel CO_2, afterwards washing down the condenser into the beer.

Example :   Acidity = 0.5% − 0.1% = 0.4%.

From the table this = 0.52 degrees of spirit indication. This is added to that previously found, e.g., 9.5.

$$9.5 + 0.52 = 10.02,$$

and from the previous table this corresponds to 45° gravity loss.

Residual gravity 1015. Corrected O. G. = 1060.

ACIDITY OF BEER CALCULATED TO ACETIC ACID AND DEGREES OF SPIRIT INDICATION

Excess % acid.	0	1	2	3	4	5	6	7	8	9
0.0	–	0.02	0.04	0.06	0.07	0.08	0.09	0.11	0.12	0.13
0.1	0.14	0.15	0.17	0.18	0.19	0.21	0.22	0.23	0.24	0.26
0.2	0.27	0.28	0.29	0.31	0.32	0.33	0.34	0.35	0.37	0.38
0.3	0.39	0.40	0.42	0.43	0.44	0.46	0.47	0.48	0.49	0.51
0.4	0.52	0.53	0.55	0.56	0.57	0.59	0.60	0.61	0.62	0.64
0.5	0.65	0.66	0.67	0.69	0.70	0.71	0.72	0.73	0.75	0.76
0.6	0.77	0.78	0.80	0.81	0.82	0.84	0.85	0.86	0.87	0.89
0.7	0.90	0.91	0.93	0.94	0.95	0.97	0.98	0.99	1.00	1.02
0.8	1.03	1.04	1.05	1.07	1.08	1.09	1.10	1.11	1.13	1.14
0.9	1.15	1.16	1.18	1.19	1.21	1.22	1.23	1.25	1.26	1.28
1.0	1.29	1.31	1.33	1.35	1.36	1.37	1.38	1.40	1.41	1.42

Long supplies an instrument which determines the O.G. by observation of the present gravity and the scale reading of a sensitive thermometer placed in the boiling beer. The scale is graduated not in degrees of temperature but in degrees of gravity. The present gravity *plus* gravity reading on the scale gives the original gravity of the beer. The instrument has to be adjusted to zero by using distilled water before carrying out the determination. The instrument should be checked against the distillation method before use, and the correction noted. The instrument is very useful where a number of determinations are required, but in which extreme accuracy is not essential.

2. *Alcohol.*

This is determined from the Sp. Gr. of the spirit from the original gravity determination by reference to the alcohol tables (see " Spirits " section). If the volume of distillate is

made the same as that of the original beer, the tables give directly the percentage of alcohol in the sample.

3. *Dry extract*

The Sp. Gr. of the distillation residue (diluted to its original volume) from the determination of the original gravity is required, the excess of this over 1000 is divided by 4·0, which gives the solids in 100 cc. of the beer. The dry extract may also be obtained by evaporation in a platinum dish and weighing.

4. *Composition of extract.*

The free maltose or low type malto-dextrins, maltose in malto-dextrin, dextrin in malto-dextrin, and stable dextrin, are determined as under "Malt extracts."

If the malto-dextrin ratio and percentage only is required the method may be shortened, as indicated under "Wort Analysis."

Moritz and Morris state that the "malto-dextrin type" (see "Malt wort") should fall between $\begin{cases} 3\,M \\ 1\,D \end{cases}$ and $\begin{cases} 1\,M \\ 3\,D \end{cases}$ The type gradually becomes lower on storage, *e.g.*, a new strong ale had $\begin{cases} 1\cdot7\,M \\ 1\,D \end{cases}$ but after storage $\begin{cases} 2\cdot4\,M \\ 1\,D \end{cases}$; ultimately it becomes so low that it disappears entirely by fermentation.

5. *Mineral matter.*

(*a*) Total ash is determined in the usual manner.

(*b*) Total chlorine. This may be determined by either of two methods :—

    (1) A measured quantity of the beer is evaporated to dryness with sodium carbonate and ashed very carefully in a muffle furnace. The chlorine is determined gravimetrically.

    (2) The sample is evaporated to dryness with a small amount of $BaCO_3$ and ignited to a black ash. The chloride is extracted with hot water and determined volumetrically.

(*c*) Alkalis. The sample is evaporated to dryness, moistened with sulphuric acid, and ashed. Potassium is determined by the chloroplatinate method and sodium by difference.

(*d*) Sulphates. The sample is evaporated to dryness with NaOH, ashed, and sulphates determined gravimetrically.

6. *Preservatives.*

(*a*) Salicylic acid. 100 cc. of beer is rendered alkaline and the alcohol evaporated off ; when cool, the liquid is neutralised with HCl, 20 cc. of saturated basic lead acetate solution, and then 20 cc. of N.NaOH solution added, and the volume made

up to 200 cc. The liquid is filtered, and 100 cc. of the filtrate is acidified with HCl, filtered, and the filtrate extracted three times with ether. After distilling off the ether, the residue is dissolved in dilute alcohol, made up to 100 cc., and the salicylic acid estimated colorimetrically by means of a fresh, weak solution of ferric chloride. The standard salicylic acid solution is 0·01% strength.

(b) Sulphites.

(i) The beer is distilled with H_3PO_4 into $N/100$ iodine solution and excess iodine determined as usual with thiosulphate 1 cc. $N/100$ iodine = 0·00032 gram SO_2.

(ii) J. L. Baker and F. E. Day (*Journ. Inst. Brew.*, 1911, **17**, 467) describe another process, of which the following is an outline :—

Marble chips and water are placed in a flask fitted with a dropping funnel and a tube leading to a condenser, the other end of which is connected with two absorption flasks containing $N/10$ iodine. A little hydrochloric acid is added through the dropping funnel, and the contents of the flask brought to a gentle boil to drive out all air from the apparatus. The beer is then added gradually from the dropping funnel (to avoid frothing), and boiling is continued for $\frac{1}{2}$ hr., during which time freshly-boiled hydrochloric acid (1 : 3) is allowed to drop in the flask. Excess iodine is titrated with thiosulphate.

7. *Saccharin.*

The following method is according to Allen (*Analyst*, 1888, **13**, 105) :—

After concentrating to 1/3rd bulk, the beer, if necessary, is made acid with pure phosphoric acid. The liquid is extracted with ether, and the extract, after evaporation of the ether, mixed with Na_2CO_3 and $NaNO_3$, and ignited. The sulphur of the saccharin molecule yields sodium sulphate, and this is estimated gravimetrically.

$$BaSO_4 \times 0·785 = saccharin.$$

Measures used in Brewing.

1 Butt	= 108	gallons	= 432	Quarts	= 864	Pints.
1 Puncheon	= 72	,,	= 288	,,	= 576	,,
1 Hogshead	= 54	,,	= 216	,,	= 432	,,
1 Barrel	= 36	,,	= 144	,,	= 288	,,
1 Kilderkin	= 18	,,	= 72	,,	= 144	,,
1 Firkin	= 9	,,	= 36	,,	= 72	..

Brewers' lbs. per barrel
= excess Sp. Gr. over 1000 × 0·36

Strength of Wort corresponding to Spirit Indication for the Evaporation Process
(Graham, Hoffmann and Redwood).

Spirit ind.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	–	0.3	0.7	1.0	1.4	1.7	2.1	2.4	2.8	3.1
1	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.0
2	7.4	7.8	8.2	8.7	9.1	9.5	9.9	10.3	10.7	11.1
3	11.5	11.9	12.4	12.8	13.2	13.6	14.0	14.4	14.8	15.3
4	15.8	16.2	16.6	17.0	17.4	17.9	18.4	18.8	19.3	19.8
5	20.3	20.7	21.2	21.6	22.1	22.5	22.8	23.4	23.9	24.3
6	24.8	25.2	25.6	26.1	26.6	27.0	27.5	28.0	28.5	29.0
7	29.5	30.0	30.4	30.9	31.3	31.8	32.3	32.8	33.3	33.8
8	34.3	34.9	35.5	36.0	36.6	37.1	37.7	38.3	38.8	39.4
9	40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.5	44.0	44.4
10	44.9	45.4	46.0	46.5	47.1	47.6	48.2	48.7	49.3	49.8
11	50.3	50.9	51.4	51.9	52.5	53.0	53.5	54.0	54.5	55.0
12	55.6	56.2	56.7	57.3	57.8	58.3	58.9	59.4	59.9	60.5
13	61.0	61.6	62.1	62.7	63.2	63.8	64.3	64.9	65.4	66.0
14	66.5	67.0	67.6	68.1	68.7	69.2	69.8	70.4	70.9	71.4
15	72.0									

Alcohol Content of Beer and Spirits
(Baumhauer-Holzner).

75 cc. of beer are distilled until almost 2/3rd of the liquid has passed over. The distillate is made up to 50 cc. and the Sp. Gr. determined. The table gives the percentage of alcohol by weight.

Sp. Gr.	9	8	7	6	5	4	3	2	1	0
0.997	1.12	1.17	1.22	1.28	1.33	1.38	1.44	1.49	1.54	1.60
6	1.65	1.71	1.77	1.82	1.88	1.94	2.00	2.05	2.11	2.17
5	2.22	2.28	2.34	2.40	2.45	2.51	2.57	2.62	2.68	2.74
4	2.80	2.85	2.91	2.97	3.03	3.08	3.14	3.20	3.26	3.31
3	3.37	3.43	3.49	3.54	3.60	3.66	3.72	3.77	3.83	3.89
2	3.95	4.00	4.07	4.13	4.19	4.25	4.31	4.37	4.44	4.50
1	4.56	4.62	4.69	4.75	4.81	4.87	4.93	5.00	5.06	5.12
0	5.18	5.25	5.31	5.37	5.43	5.49	5.56	5.62	5.69	5.75
0.989	5.82	5.89	5.96	6.02	6.09	6.16	6.23	6.29	6.36	6.43
8	6.50	6.57	6.63	6.70	6.77	6.84	6.90	6.97	7.04	7.11
7	7.17	7.24	7.31	7.38	7.45	7.52	7.58	7.65	7.72	7.79

SPIRITS.

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Determinations.

        (1) Alcohol.
        (2) Acidity—(*a*) fixed, (*b*) volatile.
        (3) Esters.
        (4) Furfural.
        (5) Aldehyde other than furfural.
        (6) Higher alcohols.
        (7) Total solids.

Distillation.

A quantity of the sample, sufficient to give approximately 50% alcohol by volume when diluted to 200 cc., is distilled until about 20 cc. remain; distillation is then continued in steam until the distillate measures 200 cc. and the residue between 10 and 20 cc. The residue is made up to a known volume.

(1) *Alcohol.*

This is determined in the usual manner from the Sp. Gr. of the distillate.

(2) *Acidity.*

(*a*) Fixed acid is determined by titration of an aliquot portion of the residue (above), using phenolphthalein as indicator, and is calculated to tartaric acid.

(*b*) Volatile acid is determined by titration of an aliquot portion of the distillate (above), using phenolphthalein as indicator, and is calculated to acetic acid. The neutralised sample is preserved for the determination of esters.

(3) *Esters.*

To the neutralised distillate from the determination of volatile acid is added 20 cc. of N/10 sodium hyroxide, and hydrolysis is effected by boiling for 1 hr. under a reflux condenser. The excess NaOH is titrated with N/10 sulphuric acid, using phenolphthalein as indicator. The esters are expressed as ethyl acetate.

(4) *Furfural.*

    Reagents.

(i) Alcohol free from aldehyde. The alcohol is purified by digesting with potassium hydroxide and fractionating, collecting the distillate between 78° and 80°C. If any coloration is

given by the distillate with aniline acetate the treatment is repeated.

(ii) Aniline acetate. Equal volumes of aniline, pure acetic acid and water are boiled together for a few minutes.

(iii) Standard furfural solution. 1 grm. of furfural is dissolved in 100 cc. of 50% alcohol, purified as above. A convenient strength for the control solution is 0·05 grm. per 1000 cc. 50% alcohol, prepared by diluting the first solution.

Determination. In a colourless spirit the determination may be carried out directly. Into two Nessler glasses are brought 20 cc. of the spirit and control solution respectively, and to each is added 1 cc. of aniline acetate solution and the colours compared after 10—15 mins. Solution is withdrawn from the darker of two until the two tints are equal. For accurate results the two solutions should be of approximately the same alcoholic strength, hence when the spirit differs from 50% it should be diluted with alcohol or water as required. In the case of a coloured spirit, the determination must be carried out on a portion of the distillate as obtained under "Distillation."

(5) *Aldehydes.*

Reagents.

(i) Schiff's reagent. 0·15 grm. fuchsine is dissolved in 150 cc. water, and to the solution are added 100 cc. sodium bisulphite solution (Sp. gr. 1·36) and 10 cc. concentrated sulphuric acid. Much mineral acid reduces the sensitiveness of the reagent, on which account J. C. Jones recommends a modification of the above (Allen's "Commercial Organic Analysis").

(ii) Standard aldehyde solution. Aldehyde ammonia is ground in a mortar with ether, allowed to settle, and the ether decanted; repeating several times. The residue is dried, first in air, and then in vacuum over sulphuric acid. 1·386 grm. is dissolved in 50 cc. of 95% alcohol purified from aldehyde (see under furfural), and 22·7 cc. of N. alcoholic sulphuric acid added, the whole made up to 100 cc. with alcohol, and a further 0·8 cc. added to correct for the volume of the ammonium sulphate precipitate. After standing over-night the liquid is filtered. The solution obtained contains 1 grm. of aldehyde in 100 cc. and keeps well. For use 2 cc. are diluted to 100 cc. with 50% alcohol; 1 cc. of the diluted solution = 0·0002 grm. aldehyde; it does not keep.

Determination. To 20 cc. of the distillate obtained as described under "Distillation." and to 20 cc. of the aldehyde standard are added 5 cc. of Schiff's reagent; after standing

20—30 mins. the tints are compared and matched by withdrawing portions of the darker one. Furfural gives only a very slight coloration with the reagent, and this may be neglected.

(6) *Determination of higher alcohols.*

(1) The Allen-Marquardt method, used in Great Britain. 200 cc. of the sample is boiled for 1 hr. under a reflux condenser with 1 cc. of strong potassium hydroxide solution; the liquid is then distilled until about 20 cc. remain in the flask, and steam is passed through until 300 cc. of distillate are collected and the residue in the flask measures about 10 cc. The distillate is divided into two portions for duplicate determinations. The liquid is brought to a Sp. gr. of at least 1·1 by adding saturated salt solution, and extracted four times with carbon tetrachloride, using 40, 30, 20, and 10 cc. respectively. A small amount of ethyl alcohol is removed by carbon tetrachloride together with the higher alcohols; this is removed by shaking with 50 cc. of saturated salt solution and then with 50 cc. of saturated sodium sulphate solution to remove chlorides. The carbon tetrachloride solution is treated with 5 grm. potassium bichromate, 2 grm. concentrated sulphuric acid, and 10 cc. of water, and the whole kept boiling for at least 8 hrs. under a reflux condenser on a water-bath. After oxidation the mixture is diluted with 30 cc. of water and submitted to distillation over a naked flame until about 20 cc. remain in the flask; steam is passed through until 5—10 cc. remain in the flask and the distillate measures 300 cc. The distillate is titrated with N/10 barium hydroxide until neutral to methyl orange, phenolphthalein is added and the titration continued. The acidity shown to methyl orange should not be more than 2 cc. or 10% of the total acidity. Each cc. of N/10 barium hydroxide required in the second stage = 0·0088 grm. of amyl alcohol.

Notes. The mean equivalent of the acids is determined by evaporating the barium salt solution after titration, drying at 130°C., and weighing. The carbon tetrachloride used must previously be boiled with chromic acid mixture for several hours and then distilled over barium carbonate. The corks used in the distillation must be covered with tin foil, if ground glass stoppers are not available; rubber stoppers must not be used.

(ii) The Rose-Herzfeld method; official method in Germany. Details of this method will be found in Allen's "Commercial Organic Analysis," vol. i, or Lunge, "Technical Methods of Chemical Analysis."

(iii) The method of Gerard and Cuniasse, as used in France. In order to remove aldehydes and furfural, 50 cc. of the 50% distillate from the original spirit is treated with 1 grm. of either metaphenylene-diamine hydrochloride, or aniline phosphate, prepared by mixing equal volumes of aniline and phosphoric acid (Sp. gr. 1·453); it is boiled gently for 1 hr. under a reflux condenser, and then distilled as rapidly and completely as possible without charring. The distillate is made up to 50 cc., 10 cc. is measured into a small flask and 10 cc. of pure conc. sulphuric acid is run carefully down the side of the flask. The flask is agitated vigorously and brought to the boil in 15 secs., then allowed to cool. The colour produced is compared with standards containing known amounts of isobutyl alcohol, and prepared in the same manner. The sensitiveness may be increased by adding about 10% of ∪ 1% furfural solution to standard and sample.

(iv) The Beckman nitrite method is seldom used. Details may be found in Lunge, " Technical Methods of Chemical Analysis."

(7) *Total Solids.*

A convenient quantity is evaporated to dryness on a water-bath. Freshly-distilled spirits leave no residue, but after storage in cask more or less non-volatile matter is taken up. The quantity rarely exceeds 100 grains per gallon.

Secondary Constituents of Brandy.

(*Lancet* Commission on Brandy; November, 1904.)

Parts per 100,000 of absolute alcohol.			
	Three Star.	Two Star.	One Star.
Acidity	77.3	65.7	65.0
Aldehydes	12.6	12.2	10.0
Furfural	1.7	2.6	2.4
Esters	110.0	103.4	97.1
Higher alcohols	120.6	108.5	80.3
	322.2	292.4	254.8

The sum of the secondary constituents (known as the coefficient of impurity) is rarely lower than 300, and the esters rarely lower than 80 in genuine brandy.

Secondary Constituents of Whisky.

Schidrowitz and Kaye (*Journ. Soc. Chem. Ind.*, 1905, **24**, 585).

Grams per 100 litres of alcohol.

	Total acid.	Non-Volatile acid.	Esters.	Higher Alcohols. (1) Colorimetric standard.	(2) Allen-Marquardt process.	Aldehydes.	Furfural.
Highland malts ..	10—31	0—35	33—185	328—864	112—235	4—66	1.6—6.3
Lowland malts ..	6—60	0—16	27—87	189—897	82—228	8—54	0—5.2
Campbeltowns ..	12—100	0—28	53—140	357—930	160—259	11—85	2.4—8.0
Islays	15—36	0—33	40—86	620—740	155—200	17—40	3.8—5.2
Grains	3—69	0—26	20—55	39—400	33—80	trace –17	0—0.9

Analyses of Genuine Jamaica Rums.

W. C. Williams, *Journ. Soc. Chem. Ind.*, 1907, **26**, 498.

Jamaica rums		Alcoholic strength % by voume.	Total solids grams per 100 cc.	Grams per 100 litres of alcohol.					
				Total acids as acetic.	Vol. acids as acetic.	Esters as ethyl acetate.	Higher alcohols as amylic.	Furfural.	Aldehydes.
"Common Clean" 21 samples	average	79.1	0.43	78.5	61.0	366.5	98.5	4.5	15.3
	maximum	82.1	1.16	155.0	146.0	1058.0	150.0	11.5	30.0
	minimum	68.6	0.01	30.0	21.0	88.0	46.0	1.0	5.0
"Flavoured" or German rums 7 samples	average	77.3	0.31	102.5	95.5	768.0	107.0	5.2	20.7
	maximum	80.6	0.61	145.0	137.0	1204.0	144.0	12.0	37.5
	minimum	66.1	nil	45.0	39.0	391.0	80.0	2.7	13.0

Specific Gravity of Aqueous Solutions of Alcohol.

(Compiled from Sir T. E. Thorpe's " Alcoholimetric Tables.")

" Proof spirit " is defined as that which at the temperature of 51°F. weighs exactly 12/13 of an equal measure of distilled water, also at 51°F.

S=Sp. Gr. 60°F./60°F.
g= weight of alcohol in 100 parts by weight of the mixture at 60°F.
V=Volume of alcohol in 100 volumes of the mixture at 60°F.
P=Percentage of British Fiscal Proof Spirit.

S	g	V	P
0.79359	100.00	100.00	175.35
0.7940	99.87	99.92	175.21
0.7950	99.55	99.72	174.87
0.7960	99.22	99.52	174.52
0.7970	98.90	99.32	174.16
0.7980	98.57	99.12	173.80
0.7990	98.24	98.91	173.44
0.8000	97.91	98.70	173.07
0.8010	97.59	98.49	172.71
0.8020	97.25	98.28	172.33
0.8030	96.91	98.06	171.95
0.8040	96.57	97.84	171.56
0.8050	96.23	97.62	171.17
0.8060	95.89	97.39	170.77
0.8070	95.55	97.16	170.37
0.8080	95.20	96.93	169.96
0.8090	94.85	96.69	169.55
0.8100	94.50	96.45	169.13
0.8110	94.15	96.21	168.71
0.8120	93.80	95.97	168.28
0.8130	93.44	95.72	167.86
0.8140	93.08	95.47	167.41
0.8150	92.72	95.22	166.96
0.8160	92.36	94.97	166.51
0.8170	92.00	94.71	166.06
0.8180	91.63	94.45	165.60
0.8190	91.27	94.19	165.14
0.8200	90.90	93.92	164.67
0.8210	90.53	93.65	164.20
0.8220	90.16	93.38	163.72
0.8230	89.79	93.11	163.24
0.8240	89.41	92.83	162.75
0.8250	89.03	92.55	162.26
0.8260	88.65	92.26	161.76
0.8270	88.27	91.98	161.26
0.8280	87.88	91.69	160.75
0.8290	87.50	91.40	160.24
0.8300	87.11	91.11	159.73
0.8310	86.73	90.82	159.21
0.8320	86.34	90.52	158.69
0.8330	85.95	90.22	158.16

S	g	V	P
0.8340	85.56	89.91	157.63
0.8350	85.17	89.61	157.10
0.8360	84.78	89.30	156.56
0.8370	84.39	88.99	156.02
0.8380	83.99	88.68	155.47
0.8390	83.60	88.37	154.92
0.8400	83.20	88.06	154.37
0.8410	82.80	87.74	153.81
0.8420	82.40	87.42	153,25
0.8430	82.00	87.09	152.68
0.8440	81.60	86.77	152.12
0.8450	81.20	86.44	151.55
0.8460	80.79	86.12	150.97
0.8470	80.39	85.80	150.39
0.8480	79.98	85.46	149.80
0.8490	79.58	85.12	149.21
0.8500	79.17	84.78	148.62
0.8510	78.76	84.44	148.03
0.8520	78.35	84.11	147.43
0.8530	77.94	83.77	146.83
0.8540	77.53	83.42	146.23
0.8550	77.12	83.08	145.62
0.8560	76.71	82.73	145.01
0.8570	76.30	82.38	144.40
0.8580	75.88	82.03	143.78
0.8590	75.47	81.68	143.16
0.8600	75.05	81.32	142.54
0.8610	74.64	80.97	141.91
0.8620	74.22	80.61	141.28
0.8630	73.81	80.25	140.65
0.8640	73.39	79.89	140.02
0.8650	72.97	79.53	139.38
0.8660	72.55	79.16	138.74
0.8670	72.14	78.80	138.10
0.8680	71.72	78.43	137.46
0.8690	71.30	78.06	136.81
0.8700	70.88	77.69	136.16
0.8710	70.46	77.32	135.50
0.8720	70.04	76.94	134.84
0.8730	69.62	76.57	134.19
0.8740	69.19	76.19	133.53
0.8750	68.77	75.82	132.86
0.8760	68.35	75.44	132.19
0.8770	67.93	75.06	131.53
0.8780	67.51	74.68	130.86
0.8790	67.09	74.30	130.18
0.8800	66.66	73.91	129.50
0.8810	66.24	73.52	128.82
0.8820	65.81	73.13	128.14
0.8830	65.39	72.74	127.46
0.8840	64.96	72.34	126.77
0.8850	64.53	71.95	126.07
0.8860	64.10	71.55	125.37
0.8870	63.67	71.15	124.67
0.8880	63.24	70.75	123.97
0.8890	62.81	70.35	123.27
0.8900	62.38	69.95	122.56

S	g	V	P
0.8910	61.95	69.55	121.85
0.8920	61.52	69.14	121.14
0.8930	61.09	68.74	120.42
0.8940	60.66	68.33	119.70
0.8950	60.23	67.92	118.98
0.8960	59.80	67.50	118.26
0.8970	59.37	67.08	117.54
0.8980	58.93	66.67	116.81
0.8990	58.50	66.25	116.07
0.9000	58.06	65.83	115.33
0.9010	57.62	65.41	114.59
0.9020	57.18	64.98	113.84
0.9030	56.75	64.56	113.10
0.9040	56.31	64.13	112.35
0.9050	55.87	63.70	111.59
0.9060	55.42	63.26	110.82
0.9070	54.98	62.83	110.06
0.9080	54.54	62.39	109.29
0.9090	54.10	61.95	108.52
0.9100	53.65	61.51	107.74
0.9110	53.21	61.07	106.97
0.9120	52.77	60.63	106.20
0.9130	52.33	60.19	105.42
0.9140	51.88	59.74	104.63
0.9150	51.43	59.29	103.84
0.9160	50.98	58.83	103.05
0.9170	50.53	58.38	102.24
0.9180	50.08	57.92	101.43
0.9190	49.63	57.46	100.62
British Fiscal Proof Spirit.			
0.91976	49.28	57.10	100.00
0.9200	49.17	56.99	99.80
0.9210	48.71	56.52	98.98
0.9220	48.25	56.05	98.16
0.9230	47.79	55.58	97.33
0.9240	47.33	55.10	96.49
0.9250	46.87	54.62	95.65
0.9260	46.40	54.14	94.80
0.9270	45.94	53.65	93.95
0.9280	45.47	53.16	93.09
0.9290	45.00	52.67	92.23
0.9300	44.53	52.18	91.36
0.9310	44.06	51.68	90.49
0.9320	43.59	51.18	89.61
0.9330	43.11	50.67	88.71
0.9340	42.62	50.15	87.81
0.9350	42.13	49.63	86.89
0.9360	41.64	49.10	85.97
0.9370	41.15	48.57	85.04
0.9380	40.65	48.04	84.10
0.9390	40.15	47.50	83.15
0.9400	39.65	46.95	82.19
0.9410	39.15	46.40	81.23
0.9420	38.64	45.85	80.26
0.9430	38.12	45.28	79.26
0.9440	37.60	44.71	78.26

S	g	V	P
0.9450	37.07	44.13	77.24
0.9460	36.54	43.54	76.21
0.9470	36.00	42.95	75.17
0.9480	35.46	42.35	74.12
0.9490	34.92	41.74	73.05
0.9500	34.37	41.13	71.98
0.9510	33.81	40.50	70.87
0.9520	33.25	39.87	69.76
0.9530	32.67	39.22	68.62
0.9540	32.09	38.57	67.48
0.9550	31.50	37.89	66.29
0.9560	30.90	37.20	65.09
0.9570	30.28	36.50	63.85
0.9580	29.66	35.79	62.60
0.9590	29.03	35.06	61.32
0.9600	28.39	34.33	60.03
0.9610	27.73	33.56	58.68
0.9620	27.06	32.79	57.33
0.9630	26.37	31.99	55.93
0.9640	25.68	31.18	54.51
0.9650	24.97	30.34	53.04
0.9660	24.23	29.48	51.53
0.9670	23.48	28.69	49.98
0.9680	22.71	27.69	48.38
0.9690	21.93	26.77	46.77
0.9700	21.14	25.83	45.14
0.9710	20.34	24.85	43.47
0.9720	19.53	23.91	41.77
0.9730	18.72	22.94	40.06
0.9740	17.90	21.96	38.35
0.9750	17.08	20.97	36.61
0.9760	16.25	19.98	34.87
0.9770	15.43	18.99	33.15
0.9780	14.61	18.00	31.42
0.9790	13.80	17.02	29.70
0.9800	12.99	16.04	27.99
0.9810	12.20	15.08	26.32
0.9820	11.42	14.13	24.66
0.9830	10.65	13.20	23.02
0.9840	9.91	12.29	21.44
0.9850	9.18	11.40	19.87
0.9860	8.46	10.51	18.34
0.9870	7.76	9.65	16.85
0.9880	7.08	8.80	15.38
0.9890	6.41	7.98	13.94
0.9900	5.76	7.18	12.53
0.9910	5.13	6.40	11.16
0.9920	4.51	5.63	9.82
0.9930	3.90	4.88	8.51
0.9940	3.31	4.14	7.24
0.9950	2.73	3.42	5.98
0.9960	2.17	2.71	4.73
0.9970	1.61	2.02	3.52
0.9980	1.07	1.34	2.33
0.9990	0.53	0.66	1.16
0.9998	0.10	0.13	0.23

Dilution of Alcohol to 30 per cent. by Volume at 15° C. (Brix).

100 cc. alcohol % by vol	water cc.	100 cc. alcohol % by vol.	water cc.	100 cc. alcohol % by vol.	water cc.
30	0.0	49	64.1	68	129.4
31	3.3	50	67.5	69	132.8
32	6 6	51	70.9	70	136.3
33	10.0	52	74.3	71	139.7
34	13.4	53	77.7	72	143.2
35	16.7	54	81.2	73	146.7
36	20.1	55	84.6	74	150.2
37	23.4	56	88.0	75	153.6
38	26.8	57	91.4	76	157.1
39	30.2	58	94.9	77	160.6
40	33.5	59	98.3	78	164.1
41	36.9	60	101.8	79	167.6
42	40.3	61	105.2	80	171.1
43	43.7	62	108.6	81	174.6
44	47.1	63	112.1	82	178.1
45	50.5	64	115.5	83	181.6
46	53.9	65	119.9	84	185.1
47	57.3	66	122.4	85	188.6
48	60.7	67	125.9		

Boiling-points of Alcohol Solutions.

Vapour °C.	% Alcohol by volume. Liquid.	Distillate.	Vapour °C.	% Alcohol by volume Liquid.	Distillate.
77.2	92	93	87.5	20	71
77.5	90	92	88.7	18	68
77.8	85	91.5	90.0	15	66
78.2	80	90.5	91.2	12	61
78.7	75	90	92.5	10	55
79.4	70	89	93.7	7	50
80.0	65	87	95.0	5	42
81.2	50	85	96.2	3	36
82.5	40	82	97.5	2	18
83.7	35	80	98.7	1	15
85.0	30	78	100.0	0	0
86.2	25	76			

Preparation of Brandy containing 24·7 per cent. by weight of Alcohol (30 per cent. by volume).

100 cc. of brandy containing % alcohol (by weight) are mixed with cc. alcohol or water at 15°C.

100 cc. alc. %	alc. cc.	100 cc. alc. %	water cc.	100 cc. alc. %	water cc.	100 cc. alc. %	water cc	100 cc. alc. %	water cc.
22.5	3.52	35	39.7	52	101.2	69	157.2	86	207.1
23	2.71	36	43.5	53	104.7	70	160.3	87	209.9
23.5	1.90	37	47.2	54	108.1	71	163.4	88	212.6
24	1.09	38	51.0	55	111.5	72	166.4	89	215.2
24.5	0.29	39	54.7	56	114.9	73	169.5	90	217.9
		40	58.4	57	118.3	74	172.5	91	220.5
cc. water		41	62.0	58	121.6	75	175.5	92	223.1
25	1.3	42	65.7	59	124.9	76	178.5	93	225.6
26	5.2	43	69.3	60	128.3	77	181.5	94	228.1
27	9.1	44	72.9	61	131.5	78	184.4	95	230.6
28	12.9	45	76.5	62	134.8	79	187.3	96	233.1
29	16.8	46	80.1	63	138.1	80	190.2	97	235.5
30	20.7	47	83.7	64	141.3	81	193.1	98	237.8
31	24.5	48	87.2	65	144.5	82	196.0	99	240.1
32	28.3	49	90.8	66	147.7	83	198.8	100	242.4
33	32.1	50	94.3	67	150.9	84	201.6		
34	35.9	51	97.8	68	154.0	85	204.4		

Composition of Fusel Oils (Windisch).

	Potato fusel oil.	Potato fusel oil. aq. and alc. free.	Rye fusel oil.	Rye fusel oil. aq. and alc. free.
	Grm. per kgm.			
Water	116.1	–	101.5	–
Ethyl alcohol	27.6	–	40.2	–
n-Propyl alcohol	58.7	68.54	31.7	36.9
Isobutyl alcohol	208.5	243.5	135.3	157.6
Amyl alcohol	588.8	687.6	685.3	798.5
Free fatty acids	0.09	0.11	1.37	1.60
Fatty acid esters	0.17	0.20	2.62	3.05
Furfurol	0.04	0.05	0.18	0.21
Hexyl alcohol, etc.	–	–	1.14	1.33
Terpene	–	–	0.28	0.33
Terpin hydrate	–	–	0.41	0.48

TANNIN MATERIALS.

W. MATHER, Assoc. M.C.T., A.I.C.

Qualitative Examination.

In the following tests, the tannin solution should contain 0·4% of tannin. A solution of this strength contains the required percentage of tannin for the quantitative estimation of the tannin, and, according to Procter, the following amounts of the different materials are required to make 1 litre of such a solution.

BARKS, &c.			Grm.	EXTRACTS.			Grm.
Algarobilla	..	..	8—9	Chestnut (liquid)	..		14
Canaigre	..	..	15—18	,, (solid)	..		7
Chestnut wood	..	..	45	Cutch	..	,,	7
Divi-divi	..	..	9	Gambier (block)	..	..	10
Hemlock bark	..	..	32—36	,, (cube)	..		10—14
Mangrove bark	..	..	10	Hemlock	..		9
Myrobalans	..	..	15	Mangrove (liquid)	..		9
Oak bark	..	..	30—36	,, (solid)	..		7
Oak wood	..	..	50—100	Mimosa	..	..	10—12
Pine bark	..	..	32	Myrobalans (liquid)	..		16
Pistacia lentiscus	..	..	20—22	Oak wood (Sp. Gr. 1·2			
Quebracho wood	..	..	20—22	or over)	..	..	15
Spent tans	..	..	50—100	Pine bark	..	..	16
Sumach	..	..	15—16	Quebracho (solid)	..		6
Valonia	..	..	14—15	,, (liquid)	..		9—13
Valonia beard	..	..	10—11				
Willow bark	..	..	36				

Preparation of Infusion for examination and estimation of Tannin.

The ground material is usually treated in a Procter extractor. The extractor is fitted up as follows : The stem of a thistle funnel is bent twice at right angles to form a syphon ; the head of the thistle funnel, covered with silk gauze, rests on the bottom of a beaker ; the other limb is lengthened by means of glass tubing connected by means of india-rubber tubing to which is fitted a screw clamp to control the rate of syphoning. The beaker is filled with well-washed sand to a point half way up the thistle head, and the necessary amount of tannin material added. 500 cc. of water are placed in the beaker, and the material allowed to soak for several hours at about 30°C. After heating the beaker and contents in a water-bath to a temperature not exceding 50°C. the liquid is syphoned off in not less than 3 hrs. The greater part of the tannin having been extracted, 500 cc. of boiling water is added in the beaker and the liquid syphoned off. The extract is cooled and made up to 1 litre with water.

Gelatin test.

A solution of 10 grm. gelatin and 100 grm. salt in a litre of water is added drop by drop to 2–3 cc. of the tannin

solution, when the formation of a precipitate or turbidity denotes the presence of some tanning material. This reaction is given by all tannins, but excess of gelatin must be avoided, as the precipitate is soluble in excess.

The tanning materials may be divided into three main classes : catechol tannins, pyrogallol tannins, mixed tannins.

Bromine water test.

Bromine water (4–5 grm. bromine per litre) is added gradually to a faintly acid solution of the tannin (acetic acid must be added if necessary), until the solution smells strongly of bromine. The formation of a precipitate, usually flocculent, generally denotes the presence of a catechol tannin. Precipitates formed only after long standing should be neglected.

Iron test.

A 1% solution of ferric ammonium sulphate is added to the tannin solution. Catechol tannins give a greenish-black coloration or precipitate; mixed tannins give a bluish- or velvet-black; pyrogallol tannins give a blue-black These reactions are quite empirical, and classification by means of them is somewhat artificial. The individual members of these groups may often be identified by their reactions with certain other reagents, including copper sulphate and ammonia, nitrous acid, stannous chloride, conc. sulphuric acid, lime water, etc. The identification is only effected by a consideration of the action of the tannin with all these reagents, as the differences between the action of a certain reagent on different tannins are frequently only of degree. Full tables for the identifications are given in Procter's " Leather Industries Laboratory Book."

Formaldehyde test. 10 cc. formaldehyde (40%), 5 cc. hydrochloric acid, and 50 cc. of the tannin solution (0·4% tannin) are boiled for half an hour in a flask under a reflux condenser. Note is taken whether the solution remains clear, or whether a precipitate is formed during the boiling. If necessary, the liquid is filtered, 10 cc. of the filtrate taken in a test-tube, 1 cc. iron alum (1%) and 5 grm. sodium acetate added, and it is noted whether a bluish-violet coloration appears. Catechol tannins are completely precipitated with formaldehyde and hydrochloric acid, the filtrate giving no violet coloration with iron. Some pyrogallol tannins (oakwood, chestnut, etc.) remain quite clear during boiling, whereas others are partially precipitated, but all pyrogallol tannins can be detected by the iron test in the filtrate.

Lead acetate test. 5 cc. of 10% lead acetate solution are added to 5 cc. of the tannin solution, and a portion of the clear filtrate is mixed with an excess of 10% caustic soda solution. A yellow coloration is produced.

Acetic acid—lead acetate test. The presence of acetic acid prevents the lead acetate from precipitating catechol tannins, whereas the pyrogallol tannins are more or less completely precipitated. 5 cc. of 0·4 per cent. tannin solution are taken, and 10 cc. acetic acid (10 per cent.) and 5 cc. lead acetate (10 per cent.) added.

Identification of Tannins (Stiasny).

50 cc. tannin solution (0·4%) boiled with 25 cc. of mixture containing 1 part conc. HCl and 2 parts formaldehyde (40%) for 30 minutes under reflux condenser.

Complete precipitation: Filtrate + iron alum and sodium acetate: no violet coloration. Inference: Catechol tannins.

- *Confirmatory tests:*
  - Original tannin solution + bromine water: ppt. + acetic acid and lead acetate: no ppt.
  - 25 cc. tannin solution (2·5%) + ammonium sulphide:
    - No precipitate. Confirmatory test with this last solution of tannin (2·5%) + iron alum.
      - *Green colrn.* Quebracho, Mangrove, Ulmo, Gambier, Pine bark, Hemlock
      - Precipitate. *Bluish violet colrn.* Mimosa, Malet

No precipitation until after 15 minutes boiling.

- Considerable precipitation after 15 minutes boiling. Filtrate + iron alum and sodium acetate: violet coloration. Inference: Pyrogallol tannins.
  - *Confirmatory tests:*
    - Original tannin solution.
    - 5 cc. tannin solution (0·4%) + bromine water.
      - *Precipitate.* Oak bark, Pistacia
      - *No precipitate.* Sumach, Divi-divi, Algarobilla, Galls, Bablah, Teri

- Inference: Mixed tannins or other materials.*
  - *Confirmatory tests:*
    - Original tannin solution + bromine water: no ppt. + ammonium sulphide: ppt.
    - 5 cc. tannin solution (0·4%) + acetic acid lead-acetate. Filtrate with iron alum soln.
      - *No coloration.* Oakwood, Valonia
      - *Violet coloration.* Chestnut, Myrobalans

* Certain non-tannin materials, e.g. gallic acid or colouring matters usually present in tannins, give precipitates with formaldehyde.

Reactions of Tannins (Stiasny).

	Formaldehyde—HCl test. During 15 mins. boiling.	Formaldehyde—HCl test. Filtrate: +iron alum +sodium acetate	Br. test.	Ammonium sulphide test.	Lead acetate test. Filtrate+NaOH.	Acetic acid +lead acetate test.	Filtrate: +iron alum.
Quebracho	ppt.	no coloration	ppt.	no ppt.	yellowish	no ppt.	green
Sulphited quebracho	ppt.	,,	ppt.	no ppt.	yellowish	no ppt. (but PbSO$_4$)	green
Mangrove	ppt.	,,	ppt.	no ppt.	colorless	no ppt.	green
Ulmo	ppt.	,,	ppt.	no ppt.	yellowish	no ppt.	green
Gambier	ppt.	,,	ppt.	no ppt.		no ppt.	green
Mimosa	ppt.	,,	ppt.	ppt.	colorless	no ppt.	deep bluish violet
Oak bark	ppt.	violet	ppt.	ppt. (after standing over-night)	colorless	ppt.	——
Hemlock	ppt.	no coloration	ppt.		yellowish	no ppt.	green
Pistacia	ppt.	deep bluish violet	ppt.	ppt.	yellow	ppt.	green to violet
Chestnut	no ppt.	no ppt.	no ppt.	ppt.	colorless	ppt.	faint violet
Oakwood	no ppt.	,,	no ppt.	ppt.	colorless	ppt.	colorless
Myrobalans	ppt.	,,	no ppt.	ppt.	colorless	ppt.	violet
Sumach	ppt.	,,	no ppt.	ppt.	yellow	ppt.	violet
Valonia	turbid	,,	no ppt.	ppt.	colorless	ppt.	colorless
Divi-divi	turbid	,,	no ppt.	ppt.	colorless	ppt.	violet
Algarobilla	turbid	,,	no ppt.	ppt.	colorless	ppt.	violet
Wood pulp	no ppt.	no coloration	no ppt.	not characteristic.	deep yellow	no ppt.	colorless

Detection of Sulphite-Cellulose Liquors in Tanning Extracts.

Procter-Hirst test. 0·5 cc. of aniline is added to 5 cc. of the solution of tanning extract, and after vigorously shaking a turbid emulsion is obtained; 2 cc. of conc. hydrochloric acid are added. If the solution becomes clear sulphite-cellulose liquors are absent; a pronounced precipitate indicates the presence of sulphite-cellulose.

Artificial tanning materials.

Artificial tannins of the Neradol type also give the Procter-Hirst reaction. Wood-pulp (sulphite-cellulose) when in admixture may be detected as follows : One or two drops of a 1% solution of alum and about 5 grm. of solid ammonium acetate are added to 10 cc. of a solution of 5% of the extract, and the mixture shaken vigorously. Wood-pulp gives a precipitate, whereas Neradol tannins remain clear.

Estimation of Tannin.

An aqueous solution containing 0·4% tannin is made up as previously stated.

(a) *Löwenthal and Schroeder's method.*

Reagents : Permanganate solution. 10 grm. of the pure salt are dissolved in 6 litres of distilled water.

Indigo solution. 30 grm. sodium sulphindigotate are dissolved in 3 litres of dilute sulphuric acid (1 : 5) ; 3 litres of distilled water are added, with stirring, until complete solution is obtained, then filtered.

Tannin solution. 2 grm. pure tannic acid are dissolved in litre of water.

Method : 10–20 cc. tannin solution, 20 cc. Indigo solution, and 750 cc. distilled water are titrated with the permanganate solution until a golden yellow coloration is produced.

A second portion is taken and the tannin removed by digesting 50 cc. for 24 hours with 3 grm. hide powder, filtering, adding Indigo solution, and titrating with permanganate in the same manner as the above solution.

(b) *Procter's Modification.*

This is practically the only titration method used in England at the present time. It is used for dilute solutions, and is not particularly affected by the presence of gallic acid. It is therefore well adapted for analyses of weak and waste liquors, spent tans, and for sumach and myrobalans.

The reagents used are :—

1. Pure potassium permanganate, 5 grm. per litre. This is diluted to 10 times its volume as required.

2. A solution of 5 grm. pure indigo carmine and 50 grm. conc. sulphuric acid per litre. This solution must be filtered.

3. Pure tannin solution, 3 grm. of tannic acid per litre.

25 cc. of the indigo carmine solution and 750 cc. water are titrated with the dilute permanganate, which is run in steadily drop by drop, the solution being rapidly stirred in a regular manner. The end point is shown by a faint pinkish rim in the yellow liquid, and is extremely delicate. This titration is repeated at least once, and the average figure taken. The process is then repeated, titrations being made in presence of 5 cc. of the tannin solution. The process is again repeated in presence of the tannin infusion under examination, the volume used being such as will consume approximately the same amount of permanganate as the standard tannin solution. The total astringent matter is then calculated as tannin.

Usually it is necessary to detannise the infusion by means of hide powder, as in the gravimetric method (see later), or by gelatin, and then to determine the amount of astringent matter other than gelatin.

OFFICIAL METHOD FROM 1907 OF THE INTERNATIONAL ASSOCIATION OF LEATHER TRADES CHEMISTS.

A quantity of air-dried hide-powder, corresponding to 6·5 grm. actual dry hide-powder, is weighed out, and mixed with about 10 times the weight of water. 10 cc. of a solution of $Cr_2Cl_3(OH)_3$ (prepared by addition of 3·9 grm. of Na_2CO_3 to 13 grm. $Cr_2Cl_6.12H_2O$ in one litre of water) are added, and the mixture churned, that is, agitated in a bottle revolving at not less than 60 R.P.M., for one hour. At the end of this period, the powder is squeezed in linen to free from residual liquor, washed with tap water, and finally with distilled water, so that on addition of one drop of 10 per cent. K_2CrO_4 and 4 drops of $N/10$ $AgNO_3$ to 50 cc. of the washings, a brick-red colour appears. The powder is squeezed fairly dry and then weighed, the weight being about 20 grm. The powder is introduced into a stoppered bottle of 500 or 1000 cc. capacity, made up to 26·5 grm. with distilled water, and 100 cc. of unfiltered tannin infusion (see below) added. The bottle is well agitated by hand or by machinery for 15 minutes, when the mixture is squeezed through linen, and the liquor filtered through a dry filter until the filtrate is clear. 50 cc. of the filtrate are evaporated to dryness in a nickel dish on the water-bath, the drying being completed in an air-oven at 100°C., and the residue is weighed (W_1).

Whilst the hide powder is being churned for one hour, the tannin infusion is made by dissolving an amount of the

substance (W) as shown in the table given (extracts in hot water; raw materials in the Procter extractor), cooling to between 15° and 20°C., and making up to 1 litre 100 cc. of this solution are used for the non-tannin estimation as above, the rest being filtered through an acid-extracted filter, the first 200 cc. of filtrate being rejected, to allow for the absorption of tannin by the filter-paper. 50 cc. of the next amount of filtrate are evaporated in a nickel dish on the water-bath, dried at 100°C. in the air-oven, and weighed (W_2).

$$\text{Total soluble matter} = \frac{W_2 \times 20 \times 100}{W} \%$$

$$\text{Soluble non-tannin} = \frac{W_1 \times 6 \times 20 \times 100}{5 \times W} \%$$

Soluble tannin = total soluble − soluble non-tannin.

HIDE POWDER.

The hide powder (batch B 8) has been tested by the Hide Powder Committee of the Society of Leather Trades Chemists with the following results :—

Moisture : 9·2%.
Acidity : 3·55c.c. N/10 NaOH per 6·5 grms. powder.
Soluble Matter : 0·782 grms.   ,,   ,,
Blank Test : 0·050 grms.   ,,   ,,
Heterogeneity : 13·1.
Relative Specific Surface : 102.

The B 8 hide powder became the official powder of the British Section of the Society of Leather Trades Chemists as from September 1st, 1921.

OFFICIAL AMERICAN METHOD.

The following tests are carried out :—

I. Crude materials.

(a) Moisture. 10 grm. of the sample are dried as under "Evaporation and Drying" (see later) until constant in weight, and loss in weight is counted as moisture.

(b) Preparation for extraction. The material is dried thoroughly at not more than 60°C., and ground through a 20 mesh sieve.

(c) Amount of sample and proportion of water. These must be adjusted so as to give 0·375 to 0·425 tannin per 100 cc. of solution.

(d) Extraction. This must be carried out under such conditions that the aqueous extract is removed from the

nfluence of continued high temperature. At least 400 cc. must be removed and not further heated, and a thin layer of cotton wool should be used in order to prevent fine matter from passing over. Gelatin-salt solution should be used to determine whether the extraction is complete.

(e) Analysis. This is carried out as for "Extracts."

II. Extracts.

(f) Preparation of solution. The extract should be weighed off in a stoppered weighing bottle at room temperature, and the amount used should be such as will give 0·375 to 0·425 grm. of tannin per 100 cc. of solution. The extract is dissolved in 900 cc. of water at 85°C., and made up to 1000 cc. after standing not less than 12, and not more than 20, hours. The solution must not be cooled below 20°C.

(g) Total solids. 100 cc. of solution are evaporated, dried, and weighed.

(h) Soluble solids. 1 grm. of well-washed kaolin is mixed with 75 cc. of the solution, and the mixture filtered through a S. and S. No. 590, or Munktell's No. 1 F 15 cm. single, pleated filter paper. The filtrate is returned to the filter paper so as to keep it full for an hour. At the end of an hour, the solution is poured off from the paper, or removed by means of a pipette. About 600 cc. of the original tannin solution is then filtered through the same paper until clear, when the filtrate is collected, and the first 100 cc. evaporated to dryness, and the residue weighed.

(i) Non-tannins. A quantity of air-dried hide powder is mixed with ten times its weight of water and 3% chrome alum in solution. The mixture is thoroughly shaken for several hours and allowed to stand overnight. The hide powder is then washed in linen until the washing gives no precipitate with barium chloride. The wet hide powder is squeezed until it contains 71 to 74% of water, and the moisture is determined on about 20 grm. of the sample. To 200 cc. of the original tannin solution is added a quantity of wet hide powder corresponding to 12½ grm. dry hide. The mixture is shaken for 10 minutes in a mechanical shaker, and then filtered through linen, and squeezed. 2 grm. of well-washed kaolin are added to the filtrate, which is then filtered through a folded filter paper (No. 1 F. Swedish is recommended), the filtrate being returned to the paper until it filters quite clear. 100 cc. of the clear filtrate are evaporated to dryness and the residue weighed.

(j) Tannin. This is the difference between the soluble solids and the non-tannins.

III. Analysis of Liquors.

(*k*) Liquors must be diluted so as to contain approximately 0·7 grm. of solids per 100 cc. of solution.

(*l*) Total solids. As under " Extracts (*g*)."

(*m*) Soluble solids. As under " Extracts (*h*)."

(*n*) Non-tannins. 200 cc. of the solution, diluted as in (*k*), are shaken with wet chromed hide powder (71--74% moisture), corresponding to dry hide powder, as in the following table :—

Tannin per 100 cc	Dry hide powder per 200 cc.
0·35 — 0·45 grm.	9·0 — 11·0 grm.
0·25 — 0·35 ,,	6·5 — 9·0 ,,
0·15 — 0·25 ,,	4·0 — 6·5 ,,
0·00 — 0·15 ,,	0·0 — 4·0 ,,

The mixture is filtered through linen, and squeezed, as under " Extracts (*i*)," and 100 cc. of the clear filtrate is evaporated to dryness and the residue weighed.

IV. Evaporation and Drying.

(*o*) This must be done in a standard apparatus known as the " Combined Evaporator and Drier," at a temperature not less than 98°C. The time allowed for evaporation and drying is 16 hours.

(*p*) For evaporation and drying, flat-bottomed glass dishes, 2¾″ to 3″ diameter, should always be used.

Percentage of Tannin.

Chinese galls	70—77%		Alder bark		16—20%
Asiatic ,,	55—60%		Mangrove bark		15—40%
Algarobilla	45%		Bearberry		14%
Catechu	40—50%		Babool bark		12—20%
Gambier	36—40%		Pistacia lentiscus		12—19%
Divi-divi	30—45%		Oak bark		10—12%
Myrobalans	30—40%		Larch		9—10%
Oak galls	25—34%		Willow bark		8—12%
Sumach	25—27%		Hemlock fir		8—10%
Mimosa bark	20—30%		Norway spruce		7—13%
Canaigre	20—25%		Birch bark		3— 5%
Quebracho wood	20%		Beech bark		3— 4%

LEATHER ANALYSIS.

W. Mather, Assoc.M.C.T., A.I.C.

The basic constituents of leather are hide fibre and combined tannins; a certain amount of uncombined tannins is essential to the quality of the leather. Chrome sole leather may contain as much as 40% of fats and waxes. Seasons and finishes may be present; for example, thin films of shellac or pyroxylin produce great water-resisting properties.

Moisture. 5 to 10 grm. of the finely-divided sample may be dried in an air-oven for 6 to 8 hrs. On account of the possible presence of oxidisable oils, moisture should preferably be calculated by difference after determination of soluble and insoluble materials.

Ash. 5 to 10 grm. of the finely-divided sample is incinerated in a tared dish until all carbon is removed.

The ash may contain calcium salts from the liming process, sodium and aluminium salts from the pickling process, chromium salts, and also salts of iron, tin, titanium, and antimony, used for the production of coloured material.

Fats. 25 grm. of the sample are extracted with petroleum ether (B.pt. 40°—60°C.) in a Soxhlet apparatus. The fats may be further investigated.

Water soluble material. The finely-divided leather is allowed to soak overnight in cold water, and is then extracted at 45°C. in a Proctor extractor, as used in the estimation of tannin materials. The solution is filtered, and a measured portion of the clear solution is evaporated, dried in the vacuum oven, cooled, and weighed. This gives the water soluble material, composed of non-tans, sugars, salts, and uncombined tannins.

The uncombined tannins may be determined in a measured portion of the aqueous extract by the method given in the "Tannin Materials" section.

Glucose may be determined as under Official American Method for Vegetable Tanned Leather (see later).

Hide substance. The nitrogen is determined in 0·7 grm. of the original leather by the Kjeldahl method, using 15 cc. of concentrated sulphuric acid and 10 grm. potassium sulphate. Hide substance contains 17·8% of nitrogen; 0·0034 grm. NH_4 correspond to 0·01573 grm. of hide substance.

The nitrogen determination is affected by the presence of dyestuffs and of proteins used as seasons and finishes.

Free mineral acid. 3 grm. of leather is placed in 25 cc. of N/10 sodium carbonate solution in a platinum basin, and the liquid evaporated to dryness on a water-bath. The mass is then raised to a dull red heat until the leather is carbonised, when the residue is extracted with boiling water, and the insoluble material filtered off. The insoluble material is ignited and the ash treated with 25 cc. of N/10 hydrochloric acid; the filtrate is added to the previous aqueous extract. The solution is then titrated with N/10 alkali, using methyl orange or methyl red as indicator, and the alkali necessary is calculated as mineral acid, usually as sulphuric acid.

Chrome determination. This is carried out as under Provisional American Method for Analysis of Chrome Leather (see later).

OFFICIAL AMERICAN METHOD FOR ANALYSIS OF VEGETABLE TANNED LEATHER.

(a) *Sample.* The sample of leather is reduced to a fine state of division by cutting or grinding.

(b) *Moisture.* 10 grams of leather are dried for 16 hours at a temperature of 95°—100°C.

(c) *Fats.* 5 to 10 grams of air-dried leather are extracted in a Soxhlet apparatus until free from grease, using petroleum ether boiling below 80°C. The ether is evaporated and leather dried to constant weight. Alternatively:—30 grams of leather are extracted as above, freed from solvent and used for the determination of water soluble materials.

(d) *Ash.* 10 to 15 grams of leather are incinerated in a tared dish at a dull red heat until free from carbon.

(e) *Water soluble material.* 3 grams of leather are digested in a percolator over night, then extracted with water at 50°C. for 3 hours. The total volume of solution should be 2 litres. Total solids and non-tannins are determined according to the Official Method for extract analysis.

(f) *Glucose.*

Copper sulphate. 34·639 grams of $CuSO_4 5H_2O$ are dissolved in distilled water, diluted to 500 cc., and filtered through asbestos.

Alkaline tartrate solution. 173 grams of Rochelle salt and 50 grams NaOH are dissolved in water, diluted to 500 cc. allowed to stand 2 days, and filtered through asbestos.

Normal lead acetate solution. A saturated solution of normal lead acetate.

Determination. 200 cc. of leather extract of analytical strength are placed in a 500 cc. flask, 25 cc. of a saturated solution of normal lead acetate added, the whole frequently shaken, and then filtered. To the filtrate is added an excess of potassium oxalate, the whole mixed for 15 minutes, and then filtered until clear. 150 cc. of clear filtrate are placed in a 600 cc. flask, 5 cc. of conc. HCl added, and boiled under a reflux condenser for 2 hours. The cooled solution is neutralized with anhydrous sodium carbonate, made to 200 cc. and filtered. The dextrose in the solution is then determined. 50 cc. of the clarified and neutralized solution are added to a mixture of 25 cc. of the copper sulphate solution and 25 cc. of the alkaline tartrate solution, heated to boiling in exactly 4 minutes, and boiled for 2 minutes longer. The solution is immediately filtered through asbestos, the precipitate washed thoroughly with hot water, then with alcohol, and finally with ether, dried for half-an-hour in a water oven and weighed as cuprous oxide, the amount of dextrose being determined by the use of Munson and Walker's table (Bull. 107, Revised, *American Bureau of Chemistry*, page 243).

(*g*) *Nitrogen.* Gunning modification of Kjeldahl method, using 0·7 gram of leather.

PROVISIONAL AMERICAN METHOD FOR THE ANALYSIS OF CHROME LEATHER.

Chrome Determination. 3 grams of leather are ashed, the ash well mixed with 4 grams of a mixture of equal parts of sodium carbonate, potassium carbonate and powdered borax glass, and fused for 30 minutes. The mass is cooled, dissolved in hot water containing enough HCl to make the solution acid, and filtered. The filtrate is made up to 500 cc., 100 cc. of which are taken, 5 cc. HCl added, and the Cr_2O_3 determined by titrating with N/10 sodium thiosulphate, using KI and starch as indicator. One cc. of N/10 thiosulphate is equivalent to 0·002533 gram Cr_2O_3.

CELLULOSE AND PAPER.

C. F. Cross, B.Sc., F.I.C., F.R.S.

The *raw materials* of the paper mill which require the control of the chemist are : (*a*) Vegetable fibrous materials, and (*b*) chemical agents used in the process of preparing these raw materials, and making the prepared fibre into paper or boards. Methods under (*a*) are special to the industry ; those under (*b*) are for the most part those of general laboratory practice, *e.g.*, the analyses of waters, fuels, soda, soaps, bleaching powder, acids, sulphates of alumina, gelatin, and colouring matters.

(*a*) Raw fibrous materials are all of " natural " origin and include : (1) original products of plant life, *e.g.*, esparto, straw, Adansonia bast ; (2) materials prepared and concentrated by mechanical treatment of the original forms, *e.g.*, flax and hemp scutching waste, jute cuttings, cotton hull fibres ; an important supply is in the form of (3) textile waste of all kinds from the spinning, rope and twine industries, cuttings of cotton, flax, and hemp cloths, and used fabrics of all kinds ; lastly, a supply of equal importance takes the form of (4) " pulp," *i.e.*, a fibrous mass representing the essential useful structural elements of the plant or plant tissue separated and concentrated by chemical or mechanical treatment of original raw material, *e.g.*, wood pulps, straw half stuff, rag half stuff.

The standard method of investigating these raw materials, especially those of classes (1) and (2), is that devised by Cross and Bevan (*J.C.S.*, 1883, **43**, p. 25 ; compare *Rep. Ind. & Col. Exhib., London*, 1886), which includes :

(1) Estimation of moisture ; the loss in weight at 100°C. is determined.

(2) Inorganic matter (ash).

(3) Oil, wax, resin, by continuous extraction in a Soxhlet apparatus with special solvents.

(4) Alkaline hydrolysis. The material is boiled with 1 per cent. caustic soda solution for (*a*) 5 minutes, (*b*) 60 minutes, and the loss in weight due to the removal of hemicelluloses determined.

(5) Cellulose estimation by chlorination method, following the alkaline hydrolysis.

In connection with paper-making, the main factors of value are the cellulose content, and the dimensions and form of the ultimate fibres.

Estimation of cellulose.

Cellulose is relatively resistant to alkaline hydrolysis, to the

action of chlorine gas, and to the action of oxidising agents, *i.e.*, to reagents which attack the hemicellulose, pectic compounds, lignone (and Cutose), which make up the "non-cellulose" aggregate, associated with the celluloses in the natural fibrous products.

The cuticular elements of fibre-aggregates are fractional in amount, and generally negligible. In cases where they have to be taken into account, the special methods of König (*Zeitschr. Farb. Ind.*, 1911, 1912, Vols. 11, 12) should be studied, and also an investigation by the author, "Cutocellulose Composition and Constitution" (*J. Soc. Dyers and Col.*, 1919, **35**, 70).

The material is carefully sampled, weighed in the air-dried state,—the "moisture" being estimated in a blank sample, weighed at the same time,—and boiled in 10—15 parts by weight of 1 per cent. caustic soda solution at constant volume, for 10—60 minutes, according to the proportion (10—60 per cent.) and character (pectous or lignified) of the non-cellulose considered to be present.

The boiled fibrous mass is transferred to a cotton cloth filter, washed thoroughly, and well squeezed so that the fibre retains not more than its own weight of water. It is then detached, opened out, placed in a beaker, and exposed to a full atmosphere of well-washed chlorine gas for one hour. The residual chlorine is removed, and the fibre covered with a known volume of water; an aliquot portion of the solution is titrated, and the amount of hydrochloric acid formed calculated. This is a useful indirect measure of lignone in the sample. (See Cross and Bevan, "Cellulose," p. 104.) After washing from acid, the chlorinated fibre is placed in a 2 per cent. solution of sodium sulphite (crystals), and slowly raised to the boil; 0·1 per cent. of caustic soda, calculated on the weight of the solution, is then added. This completes the removal of the soluble products. The fibre (cellulose) is then washed on a cloth filter, finally with a small amount of dilute acetic acid, water-squeezed, and opened out on a paper tray to dry.

It is sometimes necessary to repeat the chlorination as in the case of highly lignified aggregates, such as wood; but by intensifying the preliminary alkaline treatment the densest woods may be resolved in a single chlorination.* The cellulose may retain small amounts of coloured bodies; these are easily removed by immersion in dilute hypochlorite, or in 0·05 per cent. permanganate, in both cases followed by a wash with sulphurous acid, and finally with water until neutral.

* See also "The Determination of Cellulose," W. H. Dore, *J. Ind. Eng. Chem.*, xii, 264 (1920).

It may be remarked that in the alkaline treatment of raw materials as described above, iron boiling vessels may conveniently be used. With regard to filtration, it will be obvious that in many cases the fibre itself will act as a filter when supported in an ordinary funnel; also that paper filters are inadmissible. There are advantages in the use of bleached cotton cloths, which may be either supported in funnels, or attached to rectangular wooden frames. Wire gauze, such as papermakers' machine wire, may be used, in which case it is better to have a rectangular supporting frame of wood. Attention must be paid to the dimensions of the mesh. In washing a disintegrated mass which contains cellular celluloses of small dimensions (under 1 mm.), these are forced by careful washing through the wire gauze sieve, and separated from the fibres proper, *i.e.*, of dimensions 1–5 mm. and upwards.

Ultimate fibres.

The cellulose thus chemically isolated is invariably resolved into ultimate fibres. The dimensions of these are estimated by microscopic examination. Of particular importance are the lengths, and average length, which are constants of the celluloses.

For details of microscopic work and manipulations a standard hand book of histology must be consulted. (See also Cross and Bevan, " Papermaking," Chaps. 3 and 4.)

The following table shows the variations in length of ultimate fibres, and of the staple textile fibres :

	Length of Fibre. mm.	Diameter. mm.
Fine textiles :		
Cotton	20 — 40	0·012 — 0·037
Flax	25 — 30	0·015 — 0·037
Rhea	60 — 200	0·030 — 0·070
Hemp	15 — 20	0·016 — 0·050
Coarse textiles and rope-making :		
Jute	1·5 — 4·0	0·020 — 0·025
Sisal	1·5 — 6·0	0·015 — 0·026
Phormium	5·0 — 15·0	0·010 — 0·020
Paper-making only :		
Pinewood (tracheids)	1·0 — 3·0	0·015 — 0·020
Esparto	0·5 — 3·0	0·010 — 0·018

All the above furnish staple raw materials for papermaking; it will be evident that the fibres of the first class occur in papers in the form of fractions of the natural individuals.

A more practical assay of cellulose imitates the conditions

of mill treatment. The raw materials are treated with 10–20 per cent. of their weight of caustic soda, in the form of more concentrated solution, *e.g.*, of from 2 to 4 per cent. NaOH. Digestion may be at ordinary boiling temperature, in open iron vessels, or at temperatures up to 150°C. in **digestors or autoclaves.**

After the alkaline digestion, which may be studied in gradually increasing concentrations until the optimum is reached, the mass is fully washed on wire gauze, filtered, thoroughly washed and squeezed. The whole is weighed and a fair sample, say 1/10 of the weight, is removed and dried, for yield of half-stuff. It is generally necessary to subject it to the *bleaching test.* For this a quantity of stock solution of bleaching powder, the " active chlorine " content of which is known, is taken, to contain from 10 to 20 per cent. of the weight of the cellulose half-stuff of original dry bleaching powder, and the volume of diluting water is such as to represent 20—30 times the weight of the half-stuff. The stuff is well stirred into the bleaching liquor to perfect mixture; the time is noted, and to determine the rate of exhaustion small quantities of liquor may be drawn off at different stages, and the residual chlorine determined. For the full test the material is left for about 16 hours in contact with the bleaching solution in the cold, and the residual chlorine then estimated.

The bleached cellulose is transferred to a cloth filter, washed with water and then with a small amount of dilute sulphurous acid, and again with water, and broken up to air-dry. The air-dried weight and the portion of the sample dried at 100°C., should give the weight of the actual cellulose.

It is found that the laboratory method of alkaline hydrolysis and chlorination gives higher yields of cellulose than the assay processes just described This results from the fact that resistance to attack is a relative quality, and that in the more severe treatments in the latter process the celluloses are attacked and partly degraded to products soluble in alkaline liquors.

The celluloses as ultimate fibres are structural individuals of definite character, and are readily identified under the microscope, even when " beaten " to papermaking length (2–4 mm.). The cellulose of the gramineæ (esparto, straw, etc.) are distinguished by a colour reaction, becoming rose-red on boiling with a solution of aniline salt (hydrochloride). In admixture with other celluloses (cotton, wood, etc.), as in many papers, the depth of colour is an approximate measure of their proportion.

E 2

The following classification of the fibrous celluloses is generally adopted :

	% Carbon.	% Furfural	Fehling's soln.
A. Cotton, flax, hemp, ramie	44·0 — 44·4	0·2 — 0·5	no reduction.
B. Wood (conifers)	43·0 — 43·5	2·0 — 3·0	slight reduction.
C. Esparto	44·0	12 — 13	slight reduction.
D. Straws (cereals)	42·5 — 43·5	12 — 13	considerable reduction.

The furfural is obtained by boiling with hydrochloric acid (Sp. Gr. 1·06), and estimated as phloroglucide (see " Text-Book of Paper Making, Cross and Bevan, 5th Edition) ; the test with Fehling's solution is carried out with the diluted solution (1:5) at the boil.

The celluloses are fully oxidised to ultimate products (carbon dioxide and water) by chromic acid in presence of sulphuric acid. The carbon may therefore be estimated by the moist combustion method, in terms of chromic acid; or in presence of concentrated sulphuric acid the combustion may be carried out in connection with gas-measuring apparatus, and the carbon content calculated from the volume of gas evolved (*J.C.S.,* 1888, **53**, 889). Raw materials of the fourth class (see above) are mostly supplied to British paper-makers in the form of pulp, and in sheet or rolls. The pulp market is ruled by the convention of " air-dry pulp containing 10 per cent. moisture," and is usually delivered in the air-dry form ; but to a certain extent as moist pulp with 50 per cent. moisture. In either case the actual moisture is a variable, and since the value of any parcel is that of its content of " air-dry, 10 per cent. moisture," it is always subjected to a moisture test. In this test the importance of sampling is paramount. The ruling convention is to draw sample bales, 2–4 per cent. of the total parcel ; to cut from these a fair sample, and to re-sample this intermediate bulk for drying at 100°C. in the laboratory. The methods are those of experts, and special manuals must be consulted (see, for example, Sindall and Bacon, " The Testing of Wood Pulp ").

The wood celluloses (pulps) are delivered unbleached and bleached. The former may require testing for bleaching capacity, *i.e.,* the proportion of bleaching powder consumed in bringing it to standard white. The general basis of such methods has been indicated above ; for particulars and details the technical manuals should be consulted. (See above, " The Testing of Wood Pulp.") The bleached celluloses are for

special purposes tested for the condition of the cellulose. By treatment with caustic soda these are resolved into :

α-Cellulose, resistant to caustic soda.

β-Cellulose, dissolved by caustic soda, and reprecipitated by acetic acid.

γ-Cellulose remains soluble in the acidified filtrate from β-cellulose.

The details of the method adopted are of less importance than rigorous uniformity of *all* the conditions of treatment, a method being devised according to the special purposes for which the pulp may be required.

As a further illustration of this point, it may be noted that there is a wide divergence between a " normal pure cotton cellulose " and bleached cotton cellulose conforming with market standards, whether cloth, yarn or pulps (" rag "). The " normal " cellulose is required by the calico printers and by the makers of gun-cotton. The calico printers' test of the bleached goods is empirical, being based on their resistance to colouring matters in the dye-bath, notably to Alizarin. If degraded by hydrolysis or oxidation, cellulose develops an increasing affinity for colouring matters ; hence, in dyeing mordant-printed cloths, the " whites " of the ground cloths are spoiled. A normal cotton cellulose answering such test, in the form of cloth, will show only a fractional loss of weight when mercerised, washed, soured, washed, and dried. Reputed pure cellulose, as, *e.g.*, " Swedish " filter-papers, are often found to lose 2–5 per cent. in weight, *i.e.*, β and γ-cellulose.

The normal cellulose of the specification for bleached cottons to be converted into cellulose nitrate (gun-cotton), is defined in negative terms as follows :

Mineral matter	Not to exceed 0·5%	
Loss of weight on *boiling* with 3 per cent. solution of caustic soda for 15 minutes	,, ,,	3·0%
Boiled with 1 part of Fehling's solution and 2 parts of water copper reduced (as Cu_2O).	,, ,,	1·0%

The last item, in its quantitative form, is now generally known as the *Copper Number*. A method devised by C. Schwalbe (*Berichte*, 1907, **40**, 1347) has been generally adopted which critically discriminates between the CnO (hydrate) combining, as such, with the cellulose hydrates and the CnO reduced : the latter being an empirical measure of degradation under the action of the alkali with liberation of reactive CO groups. The " copper number " is now generally included

as an item in the specification of quality of cellulose (bleached wood pulps) to be employed in the manufacture of Artificial Silk (viscose process), for which the method devised by —. Braidy (*Rev. Gen. Mat. Col.*, 1921, **25**, 35) has advantages. The method is carried out as follows (*cf.* Clibbens and Geake, *Shirley Institute Memoirs*, 1923, **2**, 383.) :—

The solutions used in the determination are :—

(a) Pure copper sulphate, $CuSO_4.5H_2O$ ......100 grm.
Water ....to 1 litre.

(b) Sodium bi-carbonate ....50 grm.
Crystallized sodium carbonate ....350 grm.
Water ....to 1 litre.

Immediately before use, 5 cc. of solution (a) are run from a burette into 95 cc. of solution (b), the mixture is raised to the boil and poured over 2.5 grm. of the material to be examined, contained in a conical flask of capacity only very slightly greater than 100 cc. By means of a glass rod, the cellulose is distributed through the liquid and any air bubbles are allowed to escape, after which the flask is closed with a pear-shaped glass bulb, and is then immersed in a rapidly boiling, constant-level water bath. The flask should be deeply immersed in water, and care should be taken to cover the top of the bath sufficiently to prevent cooling of the reaction mixture by currents of cold air; several determinations may be carried out simultaneously in a suitable bath. The flask is allowed to remain in the boiling water for exactly three hours; the contents are then filtered with suction, and the cellulose, impregnated with cuprous oxide, is washed, first with dilute sodium carbonate and then with hot water. The cuprous oxide is dissolved by treating the cotton on the filter with the following solution :—

(c) Iron alum .... 100 grm.
Concentrated sulphuric acid .... 140 cc.
Water ....to 1 litre.

Two portions of the solution, of volume 15 cc. and 10 cc. respectively, are usually sufficient for this purpose, though a further treatment with 10 cc. may occasionally be necessary in the case of highly reducing products. The cellulose is then washed with $2N$ sulphuric acid, and the combined filtrates and washings are titrated with standard potassium permanganate solution of concentration approximately $N/25$, corresponding

to about 2.5 mgrm. of reduced copper per cubic centimetre. The end-point of the titration is sharp and stable. For the exact figure (copper number) the solution is exactly standardized, and the result calculated to 100 of cellulose.

Oxycellulose, Hydrocellulose, and *Hydrate-cellulose* are terms applied to cellulose derivatives, products of reactions with oxidants, acids, alkalis and certain salts. They are, however, not to be regarded as chemical individuals—whereas the normal cotton cellulose justifies such description in so far that it is homogeneous as a reacting aggregate (in synthetic reactions); the derivatives resulting from the attack of oxidants and acids are mixtures of degradation products.

In examining cellulose materials for the presence of these derivatives, the following typical characteristics are to be noted :

Oxycelluloses, as formed by the action of hypochlorous acid on cotton, have a marked affinity for basic dyes. The standard test, or rather method of diagnosis, is that of comparative dyeings in baths of Methylene blue of 1·0—0·1 per cent. concentration.

Hydrocelluloses, as formed by the action of halogen hydracids on celluloses, are structurally disintegrated, and the microscope reveals the brittle condition of the modified fibre substance. They are characterised by a much reduced (30—50 per cent.) affinity for atmospheric moisture. Like the oxycelluloses, they have the reactions of aldehydes.

Hydrate-celluloses are formed with visible hydration effects, as in mercerising with solutions of caustic soda (15—17 per cent. NaOH), or on heating with zinc chloride solution (50 per cent ZnCl₂). They are characterised by increased (20—30 per cent.) affinity for atmospheric moisture. They absorb cupric hydroxide from cold alkaline solutions, e.g., Fehling's solution, but give no aldehyde reaction on boiling (reduction). The absorbed CuO may be quantitatively estimated by various and obvious methods, and is recognized as a measure of comparative states or degrees of hydration (Schwalbe).

The " wood pulps " include " mechanical " pulps, or wetground wood, composed therefore of the entire wood substance, or ligno-cellulose, less adventitious substances dissolved, and removed in the process of wet grinding, followed by running in suspension in water on the endless-running wire cloth of the machine.

The ligno-celluloses are highly reactive by virtue of their lignone components, which are unsaturated aldehydes and ketones. (See Cross and Bevan, " Cellulose," pp. 89—214.) They react not only with the halogens, but absorb large

amounts of oxygen, and cannot be bleached with the ordinary bleaching agents, nor indeed at all, within economical limits. They combine with the synthetic colouring matters of the most varied constitutional types, and also with aromatic amines and phenols to form coloured derivatives. With the monamines (aniline, etc.) the products are yellow. More characteristic is the magenta coloured derivative formed with dimethyl-p-phenylenediamine; not only is the depth of colour considerable, but uniform for specimens of varied origin and history. As a "constant" therefore of the ligno-celluloses, it has been adopted as a quantitative measure of the proportion present in admixture with non-reacting celluloses, as in papers. Equally characteristic and intense is the red coloration with phloroglucinol, which is a reaction of condensation determined by hydrochloric acid; this is also used as an approximately quantitative measure.

All such processes depending upon judgment of colour intensity, are liable to error proportional to the percentage of reacting substance, and therefore to the colour intensity; only up to the proportion of 30 per cent. admixture with non-reacting celluloses is there a satisfactory approximation.

A reinvestigation of this reaction, however (Cross, Bevan and Briggs, *Ber.*, 1907, **40**, 3119) has shown that the colour phase involves only about 10 per cent. of the total phenol reacting. It is a reaction of the aldehyde groups of the lignone, which are also those which react with amines. Quantitative estimations of the total phloroglucinol reacting showed that constant results are obtained, and therefore furnish a method of estimating ligno-celluloses which is free from the defects above noted. In this method advantage is taken of the interaction of phloroglucinol with aldehydes, more particularly formaldehyde and furfuraldehyde, to give a volumetric process, as follows :

10 cc. of a solution containing 0·5 grm. of phloroglucinol per 100 cc. of hydrochloric acid (Sp. Gr. 1·06) are diluted with 20 cc. of hydrochloric acid of the same strength, and the liquid heated to 70°C. The standard aldehyde solution contains either 0·4 grm. of furfural or 0·2 grm. of 40 per cent. formaldehyde dissolved in 100 cc. hydrochloric acid (Sp. Gr. 1·06), and is added from a burette 1 cc. at a time, with an interval of two minutes between each addition. At 70°C. the reaction between the phenol and the aldehyde is complete within this time. Towards the end of the titration the aldehyde solution is added in decreasing quantities, but with the same interval between each addition. The course of the titration is followed by placing a drop of the liquid on a piece of ordinary

newspaper (70—80 per cent. ligno-cellulose), a red stain being produced as long as the phloroglucinol is in excess. (The reaction is perceptible at a dilution of 1 in 30,000 of the phenol.) Near the end-point it is necessary to dry the spot at a gentle heat before the stain appears For the estimation of the quantity of phloroglucinol reacting with a given ligno-cellulose or mixture, 2 grm. of the finely-divided material, fibre or paper, are dried at $100°$C., weighed, placed in a dry flask, and covered with 40 cc. of the phloroglucinol solution. After standing for about 16 hours the liquid is strained through a small plug of cotton wool, and 10 cc. are taken for titration. The difference between the two titrations gives the quantity of phloroglucinol reacting with the ligno-cellulose. This is expressed as a percentage on the dry fibre substance. In the analysis of papers, the fibre substance is estimated approximately by deducting the weight of the mineral matter (ash) and 1.5 per cent. for sizing constituents from the dry weight of the paper. The following numbers have been determined :

Phloroglucinol absorption values as percentage of dry fibre.

Wood flour	7·50
Mechanical wood-pulp	6·71
Jute (best white)	3·98
Jute (ordinary)	4·23
Sulphite wood-pulp	0·75
Esparto cellulose	0·50
Cotton	0·20
Hydro-cellulose from cotton	0·42
Hydro-ligno-cellulose from jute... ...	4·54

The *chemical* examination of papers is a subordinate matter. Quality and value are determined more by fibre composition, which is ascertained by microscopic analysis,* and by physical constants, which can be tested and expressed in numerical terms, such as breaking strain, elasticity, bursting strain, specific volume, etc. The composition of pulp or pulp "furnish," determined by microscopic examination may be controlled by the chemical constants of the component fibre substances, *c.g.*, by determination of yield of furfural on boiling with hydrochloric acid (Sp. Gr. 1·06). In mixtures containing ligno-celluloses these are estimated by one of the methods above described.

* Recent researches (Spence and Krauss) have established relative weights of fibres for unit dimensions by optical estimation (*Paper Making,*" Cross and Bevan, Fifth Edition, p. 414).

(b) Non-fibrous Components of Paper. The adventitious constituents of general importance are : mineral matter, sizing constituents, and, in coloured papers, the colouring agents employed.

Mineral matter is determined as total ash, which may be the natural ash of the fibre components, or added loading matter, *e.g.*, china clay in papers of medium quality, calcium sulphate in higher class writing papers, barium sulphate (*blanc-fixe*) and *satin white* (alumina and calcium sulphate) in coated art papers. These are identified or estimated by the usual systematic analytical methods.

For the identification of *colouring matters* and *pigments* the section on "Dyestuffs" is to be consulted.

Sizing agents. Starch may be identified by the usual reaction with iodine. Resin, or resin acids, are detected by extraction with alcohol-ether containing a small amount of acetic acid; on pouring into water the dissolved resin acids form an emulsion. In estimating the quantity, which, however, is seldom necessary, the paper can be extracted in a continuous extraction apparatus, the residue isolated and weighed.

In tub-sized papers, which may contain from 2 to 9 per cent. of gelatin, the estimation of gelatin is usually carried out in terms of total nitrogen by the Kjeldahl method. A more rapid process depends upon the reaction of the amino-groups of gelatin with chlorine in constant proportion to form chloro-amines, the chlorine of which reacts as hypochlorite chlorine, and may be conveniently estimated by means of standard arsenite solutions (*J. Soc. Chem. Ind.*, 1908, **27**, 260).

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TEXTILE FIBRES.

W. F. A. ERMEN, M.A.

METHODS OF DISTINGUISHING ANIMAL AND VEGETABLE FIBRES.

The material to be examined is boiled alternately with very dilute sodium carbonate and hydrochloric acid until organic finishing matters have been removed; it is then well washed, dried, and the following tests carried out:

(1) On ignition in a porcelain crucible vegetable fibres evolve vapours which are acid to litmus and have the odour of burning wood. The carbonaceous residue rapidly burns away, leaving only a trace of light ash. On similar treatment, animal fibres melt, give off alkaline vapours with the smell of burning feathers, and leave a lustrous residue of carbon which burns away very slowly.

(2) The vegetable fibres are not visibly affected by boiling in 10% caustic soda solution, whereas animal fibres are rapidly disintegrated and dissolved.

(3) Lead acetate solution is cautiously added to a hot solution of caustic soda until a permanent precipitate is just produced. The solution is cooled and filtered, and the material shaken with it, when wool fibres slowly become brown, due to the deposition of lead sulphide in the body of the fibres; all other fibres remain colourless.

(4) To distinguish between cotton, linen and artificial silk the fibres are teased out, mounted in water and examined under the microscope. The importance of having available a set of fibres of known origin for comparison under the microscope cannot be too greatly emphasised.

Cotton fibres form translucent, twisted ribbons, somewhat thickened along the edges. After mercerisation the fibres are rather more rounded and less twisted.

Linen fibres appear as straight, transparent tubes, with characteristic swellings, which appear like the joints on a bamboo cane.

Artificial silk fibres are almost cylindrical and absolutely structureless, like glass rods.

Jute, hemp, ramie and other vegetable fibres are most easily recognised by means of their microscopic structure, but even this method of identification is difficult.

The hemp fibre closely resembles the linen fibre. but it is coarser and less lustrous. It is generally met with in the form of rope, cordage, and canvas, and sometimes woven with linen.

Jute fibres are yellowish white, and appear under the microscope as bundles of lustrous cylinders, somewhat irregular in thickness. It is a ligno-cellulose, and not a true cellulose, and hence exhibits considerable affinity for basic dyestuffs.

Ramie (China-grass) fibres are composed of pure cellulose; they differ from cotton in being softer and more lustrous. Well-marked characteristics are the pointed ends of the fibres and the bold longtitudinal striations.

Data regarding the length and diameter of textile fibres will be found under the "Cellulose and Paper" section.

Chemical tests have been proposed, but are all somewhat uncertain and apt to be misleading; colour reactions are unreliable, owing to varying treatment of the fibres in degumming, scouring, bleaching, dyeing, mercerising, etc.

(5) True silk is almost instantly soluble in cold concentrated hydrochloric acid, whereas Tussah silk is only affected after 48 hours. This reaction may be used quantitatively. On examination under the microscope, silk in the gum will show twin fibres.

(6) Diphenylamine dissolved in pure sulphuric acid gives the following colorations :

True silk	Brown.
Tussah silk	Intense brown.
Chardonnet and Lehner silk (Nitrocellulose process)	Intense blue.
Pauly and Thiele silk (Cuprammonium process) ..	No reaction.
Viscose silk	No reaction.

ANALYSIS OF FABRICS CONTAINING SILK, WOOL AND COTTON.

Moisture. About 5 grm. of the sample are weighed accurately and dried at 100°C.

Weighting materials. The sample is steeped in a cold 1% caustic soda solution, washed, and boiled for 15 minutes in 2% hydrochloric acid. These operations are repeated until nothing further appears to be removed, when the sample is well washed, dried, and weighed. In case the sample contains silk a portion of the extracted material is then ignited, and the percentage of ash determined. If more than 1% of ash is found, the sample should be further extracted with warm 1% sodium carbonate solution, followed by boiling with a 1% solution of hydrofluoric acid in a platinum basin.

Silk. This is removed by treating the sample with a cold ammoniacal solution of nickel hydroxide. The residue is filtered, washed with hot 1% hydrochloric acid, washed with water, and dried.

Ammoniacal nickel solution. 25 grm. $NiSO_4.7H_2O$ are dissolved in 100 cc. of water, and caustic soda solution added until almost all the nickel is precipitated. The nickel hydroxide is filtered off, thoroughly washed, transferred with 125 cc. water into a flask, and 125 cc. of strong ammonia added.

Wool and *Cotton.* The residue from the silk estimation is boiled for 10 minutes with a 2% solution of caustic soda, filtered, and washed until free from alkali. The residue of pure cellulose is dried and weighed. The loss in weight is the amount of wool in the sample.

COAL TAR.

W. H. COLEMAN, F.I.C.

The nature of tar depends upon the kind of coal carbonised, the design of the retort or oven, the temperature of carbonisation, the rate at which that temperature is attained and the length of time during which the volatile products are exposed to that temperature. Low temperatures, slow heating and rapid removal of the volatile products favour the formation of aliphatic hydrocarbons; high temperatures, rapid heating and a longer exposure of the volatile products to high temperature tend, on the other hand, to the formation of aromatic hydrocarbons. Recent research seems to indicate that aliphatic bodies are first formed, which on exposure to temperatures above 700°C. are converted into aromatic compounds with liberation of hydrogen.

The chief sources of coal tar are horizontal, inclined and vertical retorts at gasworks, coke ovens, blast furnaces, producers using bituminous coal, and recently some types of low temperature carbonising processes. The raw tar contains considerable but varying proportions of ammoniacal liquor and free carbon. After separating as much of the former as possible the tar is distilled. The fractions obtained vary considerably, the changes are made either by the temperature of the vapour or by the specific gravity of the distillate. Three examples of methods of fractionating follow :—

I.

1. Ammonia water and light oil up to 170° C
2. Creosote from .... 170°—270° C.
3. Anthracene oil .... 270°—350° C.

II.

1. Ammonia water & crude naphtha up to 110°C.
2. Light oil from.................. 110°—200° C.
3. Carbolic oil .... 200°—240° C
4. Heavy or creosote oil......... 240°—270° C.
5. Anthracene oil above .... 270° C.

III.

1. Ammonia water and crude benzol till water ceases.
2. Light oil till distillate has 2° Tw. at 80° F.
3. Light creosote to.......... 8° Tw. at 100° F.
4. Heavy creosote to .... 14° Tw. at 100° F.
5. Anthracene oil to .... 18° Tw. at 120° F.

TAR *(distil)*

Ammonia Water and Light Oil to 170° C. *(Separate)*

Creosote to 270° C.

Anthracene oil to 350° C. *(Cool and Filter)*

Residue Pitch

Ammonia Water (to Ammonia Plant)

Crude Light oil *(distil)*

Residue to

Heavy Oil

Crude Anthracene

Once Run **Benzol** (Washed) (1)

Once Run **Toluol** (Washed) (2)

Once Run **Solvent Naphtha** (Washed) (3)

Once Run **Heavy Naphtha** (Washed) (4)

Carbolic oil (Washed with 10% NaOH Soln.)

Creosote Oil

Anthracene oil to 350° C.

Washed Creosote *(Cool and Filter)*

Liquid Creosote

"Lucigen" or "Wells" oil

Phenolote of Soda or "Phenate," (5) (Acid phenates from once run products and decompose with CO_2)

Crude Tar Acids (treat with a little 80% H_2SO_4 an'i separate)

Crude Naphthalene **"Creosote Salts"**

"Spent Phenate" (Causticise with CaO for re-use)

Crude Tar Acids *(distil)*

Cresylic Acid

Sulphate of Soda Solution (generally run to waste)

Water (to spent phenate)

60's Carbolic Acid

90's Carbolic Acid

Bottoms to Creosote

The fractions are subsequently treated in various ways, according to the quality of the tar and the final products desired. One method is outlined on the preceding page.

1, 2, 3, 4 are separately washed, first with NaOH solution, and the phenate added to (5); then with weak H_2SO_4, and the separated pyridine sulphate solution decomposed with ammonia to obtain ammonium sulphate and crude pyridine; then with concentrated H_2SO_4 to remove thiophene and unsaturated hydrocarbons, after which the oils are washed several times with water, once with dilute NaOH, and finally with water. The washed oils are then fractionally distilled to obtain various qualities of benzol, toluol, solvent and heavy naphtha.

Crude tars differ very considerably in composition, as will be seen from the table on the following page.

In order to give some approximate idea of the final products to be expected, the working results from over 200,000 tons of mixed Lancashire tars are given below :—

	Per cent. on tar.
Benzol, 90% at 100°C.	0·5
Toluol, 90% at 120°C.	0·2
Solvent naptha, 90% at 160°C. ...	0·6
Heavy naphtha	0·2
Pyridine 90% at 140°C.	0·06
60's carbolic acid	1·4
Cresylic acid	0·9
Naphthalene	1·3
30% anthracene	0·7
Creosote and heavy oil	22·2
Pitch (medium)	68·6
Ammonia water and loss	3·34
	100·00

A table which follows gives an idea of the properties of the various products generally made. The tests were made in each case by distilling 100 ccm. of an average sample from a side-tube flask with the top of the mercury bulb of the thermometer level with the side tube. No corrections were made for the emergent stem or for barometric pressure. All figures in table, except for specific gravities, are degrees Centigrade.

No.	Description of Tar.	1 Sp. Gr.	2 % Free carbon	3 % Water	4 % distillate to 170°C	5 % distillate 170° to 270°C	6 % distillate 270°–350°C	7 % Pitch	Remarks
1.	Horizontal retorts	1.217	22.0	3.9	3.4	14.0	15.1	67.5	From large gas works, high heats.
2.	,, ,,	1.185	14.7	2.5	4.1	22.0	19.5	54.4	Moderate size works, medium heats.
3.	,, ,,	1.125	6.9	4.0	10.4	20.8	17.7	51.1	Small works, comparatively low heats.
4.	Inclined retorts	1.143	2.6	2.0	9.2	23.5	17.9	49.4	
5.	Vertical retorts	1.108	2.4	3.8	10.1	21.4	16.6	51.9	
6.	Coke ovens	1.147	4.0	2.0	4.1	24.2	18.7	53.0	
7.	Mond Producer	1.150	—	16.0	0.7	19.9	33.7	45.7	Contains no benzol but much higher cresols and some paraffin.
8.	Water gas	1.030	2.3	6.2	12.6	40.1	19.6	27.7	Much benzol and toluol but no phenols.
9.	Horizontal retorts, cannel coal	1.080	4.5	5.0	13.2	29.4	23.2	34.2	Much paraffin bodies.
10.	,, ,, Lancs. coal	1.222	21.6	4.0	4.7	11.9	17.7	65.7	
11.	,, ,, Durham coal	1.205	17.3	4.5	4.6	16.7	10.4	68.3	
12.	,, ,, S. Yorks. coal	1.220	23.2	6.0	1.5	10.6	16.0	71.9	
13.	Coke ovens, W. Cumberland coal	1.170	4.7	2.0	2.0	21.4	18.4	58.2	
14.	,, Yorkshire coal	1.115	2.1	1.5	5.0	31.0	20.2	43.8	See Note B.
15.	,, Lancashire coal	1.155	5.4	2.5	4.5	21.5	17.4	56.6	
16.	Av. of about 30 Lancashire tars	1.205	19.3	4.5	5.2	16.7	16.7	61.4	

NOTE A.—For the sake of comparison the figures in columns 4, 5, 6 and 7 have been calculated on 100 parts of total distillate and pitch.

NOTE B.—Coke oven tar No. 14 is suspicious; it has probably been mixed with spent wash oil, as is sometimes done.

NOTE C.—It must be remembered that tars are liable to vary from many causes and the above results must be looked upon simply as a guide.

Properties of Tar Products.

Substance	Sp. gr. at 60° F. 1st drop	10%	20%	30%	40%	50%	60%	70%	80%	90%	dry	Remarks.
"Pure" benzol	.884	79.8	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.1	80.6	
"Pure" toluol	.868	110.7	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.7	*(See paragraph in text.)*
90's benzol	.877	81	83.5	84	85	85	85	87	88	91.5	99	111	
50's/90's benzol	.873	86	91	92	93.5	95	97	99.5	103	109.5	119.5	142	
90's toluol	.868	103	109	109.5	110	110.5	111	112	112.5	114	118	133	
90/160 Solvent naphtha	.871	116	123	126	128	131	133	137	140.5	146	155	176	
90/190 Heavy naphtha	.898	151	159.5	162	163	165	167	169	171	175	181	194	
65/120 Recovered coke oven benzol	.895	74	85	88.5	91	94	98	104	116.5	148	196.5	220	
Crude benzol	.938	74	103	115	126	140	158	179	194	215	243	308	5% Tar acids. 2% Crude pyridine.
Light oil	1.016	143	176	187	194	200	206	211	218	225	243	308	18% Tar acids. 5% Crude bases.
Light creosote	1.037	146	203	210	217	223	231	240	253	274	313	357	17% Tar acids. 5% Crude bases.
Heavy creosote	1.065	196	232	246.5	258.5	269	282.5	301.5	319	336.5	360	390	
Anthracene oil	1.110	210	270	292	305	316	326	338	351	366	394	>400	
60's Carbolic acid	1.057	101	122	170	184	185	185	186	187	188	191	201	14% water.
97/99 Cresylic acid	1.045	183	192	192.5	193	193	194	195	196	198	200.5	206	
90/140 Pyridine	.978	98	102.5	105.5	112	117	122.5	125	127	131	137	153	5% water.

Benzols and Naphthas. (Weiss).

	Boiling point. °C.	Sp. gr. at 15° C.	Flash point °F.	Evaporation Test.*
Benzol, pure	80°—82°	.881—.884	below 32°	10 minutes
,, 100%	100% at 100°	.875—.884	,,	13½ ,,
,, 90%	90% at 100°	.875—.882	,,	14 ,,
,, 50%	50% at 100°	.871—.875	,,	23 ,,
Toluol, pure	110°—112°	.869—.871	,,	29 ,,
,, commercial	90% at 120°	.869—.872	,,	33 ,,
Xylol, pure	135°—145°	.865—.867	85°·5	89 ,,
Solvent naphtha or benzol 160°.....	90% at 160°	.864—.870	78°	107 ,,
Benzol, straw colour..........	like 90's benzol	.862—.870	below 32°	18 ,,
Toluol, straw colour..........	like coml. toluol	.862—.870	,,	36 ,,
Crude solvent naphtha..........	like solvent naphtha	.876—.887	78°	121 .
Heavy naphtha	about 85% at 200°	.925—.940	109°	303 ,,

* Time taken for 2 ccm. to evaporate from metal surface 3½ inches square.

Percentage Composition of Commercial Benzols.

(Frank).

	Benzene.	Toluene.	Xylenes.	Cumenes.	Naphthalene.
90's Benzol	84	13	3	0	0
50's ,,	15	75	10	0	0
30's ,,	43	46	11	0	0
Solvent naphtha I	0	5	70	25	0
,, ,, II	0	0	35	60	5
Heavy naphtha	0	0	5	80	15

Solvent naphtha I, to 160° C. Solvent naphtha II, to 175° C.

Methods of Testing Tar Products.

It must be borne in mind that nearly all tar tests are physical and not chemical, and, further, many are purely empirical and designed by purchasers to suit their own requirements. In America the Barrett Company have published a small book on Methods of Analysis of the Coal Tar Industry drawn up by a committee of their chemists. It is not entirely applicable to conditions in this country, and, sooner or later, the matter must be taken up by the industry in this country and a set of standard methods agreed upon. For the above reasons the methods following, whilst mostly in general use, are not accepted universally.

CRUDE TAR.

Sampling. Owing to its viscous nature the only satisfactory method is to take samples at frequent intervals as the tar is flowing from one vessel to another. The samples are to be thoroughly mixed and a final sample taken from the mixture without delay.

Specific gravity. For most purposes this is taken with Twaddell's hydrometer, the tar being warmed slightly to render it less viscous. A more accurate method is to weigh a dry, empty 250 cc. graduated flask (W 1), fill it to within a few centimetres of the graduation with tar, using a long funnel, and taking care that the neck of the flask above the graduation is not soiled. The flask and tar are then weighed (W 2). The flask and tar are then allowed to assume the temperature of the balance room, and then filled to the mark

with distilled water and weighed again (W 3). The flask is then cleaned, filled to the mark with distilled water at the temperature of the balance room and weighed again (W 4). Then

$$\text{Sp. gr.} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

Water. 100 ccm. of the well-mixed sample is distilled, preferably from a copper flask, up to a temperature of 200°C. The distillate is caught in graduated cylinders and the volume of water read off after cooling. If separation is difficult a few ccm. of *dry* benzol added to the distillate will generally do away with any trouble. If the tar tends to boil over the flask should be heated at the side only and from 50 to 100 cc. of *dry* heavy naphtha or cresylic acid may be added to the tar before distillation.

Free carbon. 10 grammes of the sample are placed in a flask and 25 ccm. of glacial acetic acid and 25 ccm. toluene are added. The flask is warmed to 100°C. and well agitated, the contents filtered through a double, balanced filter, and washed with boiling benzol until the filtrate runs through colourless. The filter, together with its contents, is dried at 100°C. and weighed, the outer filter being used as a tare.

Laboratory tests of tar for yield of products are not satisfactory. The only way to obtain a real insight into the value is to distil 10—15 tons on the large scale, measuring, weighing and testing the fractions obtained. If, however, it is absolutely imperative to make a laboratory test, *at least* 2,000 grammes should be distilled from a copper flask, making the fractions in the same way as on the works and measuring, weighing and testing them. For purely comparative purposes and to check deliveries, 100 ccm. of the well-mixed average sample may be distilled from a side tube flask, with the thermometer bulb in the vapour, noting the percentages of distillate at 170°, 270° and 350°C., reading off the water and weighing the pitch.

CRUDE BENZOLS AND LIGHT OILS are tested for specific gravity and for percentage of tar acids. The latter test is made by washing 100 cm. of the sample with an excess of 10% NaOH solution and noting the contraction, or the phenate solution may be separated, decomposed with dilute H_2SO_4 and the liberated tar acids measured.

Test for yield of finished products. 100 ccm. of the sample

is distilled from a retort up to a temperature of 193°C., the bulb of the thermometer being $\frac{2}{3}$ in. from bottom of retort. The measured distillate is then washed as follows :—(1) With about 50 cc. 10% NaOH solution, (2) with water, (3) with 4% of its volume of 168°Tw. H_2SO_4, (4) with 4% more H_2SO_4, (5) with a very small quantity of water run down the side so as to avoid forming an emulsion, (6) a repeat of (5), (7) with a large water wash, (8) with about 20 ccm. of 10% NaOH, (9) with several water washes until neutral. The oil is then separated and re-measured, the difference being reported as loss on washing. The washed oil is then fractionated, using four Le Bel Henniger bulbs or other equally efficient column, and the following fractions collected separately : Benzol up to 101°C., toluol to 121°C., solvent naphtha to 166°C., and heavy naphtha to 195°C. The products may be taken as approximately of 90% quality.

BENZOL, TOLUOL AND NAPHTHAS. The commercial test for these products is carried out by distilling 100 ccm. from a glass retort with the bulb of the thermometer $\frac{2}{3}$ in. from the bottom.

90's benzol should give 90% distillate at 100°C.
90's toluol should give 90% distillate at 120°C.
50's/90's benzol should give 50% at 100° and 90% at 120°C.
90's/160's solvent naphtha should give 90% at 160°C.
Heavy naphtha should give 90% at 190°C.

Pure benzol and pure toluol are distilled from a flask, using a standard thermometer graduated in 1/5 or 1/10°C. 100 ccm. is measured out in a graduated cylinder and poured into the flask, and distillation carried out at the rate of about one drop per second, using the same cylinder, without cleaning, as receiver, and noting the temperature when the first drop leaves the end of the condenser, when 3 ccm. have collected in the receiver and when the flask is dry. When cool the residue in the flask is poured into the cylinder and the defect from 100 ccm. is noted as loss. The difference in temperature between the 3 ccm. and the dry point should be less than 0·5°C.

Percentage of benzol and toluol in commercial samples may be estimated by Dr. Colman's method (*J.S.C.I.*, 1915, p. 168, and 1919, p. 57).

The fractionation is carried out in a standard apparatus and the percentages distilling below 105°C. and above 117°C. noted. The percentage of toluene in the sample is ascertained from a table which is given in an abbreviated form.

Percentage of Toluene in Commercial Toluol. (Colman).

Percentage boiling below 105°C.

Percentage boiling above 117°C.	5	8	11	14	17	20	23	26	29	32	35	38	41	44	47	50
50													53	52	53	51
47												51	57	55	57	55
44										52	50	55	60	58	61	59
41									50	55	53	58	63	62	64	63
38	52						51	52	53	58	57	62	66	65	67	66
35	54		50		52	50	54	55	57	61	60	65	70	68	71	70
32	57	52	53	51	55	53	57	58	60	64	63	67	73	72		
29	60	55	56	54	58	56	60	61	63	67	66	71				
26	62	58	58	57	61	59	63	64	65	70	69	74				
23	64	60	61	60	63	62	65	67	68	72	72					
20	67	63	64	63	66	64	68	69	71	75	75					
17	69	65	67	65	68	67	71	72	73							
14	72	67	68	67	71	69	73	74								
11	74	70	71	69	73	72	75									
8		73	73	72	75	74										
5		75	75	74												

Mixtures of Benzene and Toluene.

% Benzene	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	
% Toluene	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
°C																			
81	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
82	6	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
83	65	15	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
84	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
85	87	70	40	8	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
86	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..
87	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
88	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
89	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
90	95	90	82	74	62	49	37	21	7	1	..	..	..	..	..	..	..	..	..
91	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
92	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
93	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
94	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
95	97	94	91	87	79	75	69	61	51	38	24	7	2	..	..	..	..	..	..
96	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
97	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
98	100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
99	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
100	..	96	94	92	88	85	82	77	72	65	57	48	37	25	8	1	..	..	..
101	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
102	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
103	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
104	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
105	..	100	96	95	93	91	89	87	84	80	77	71	67	60	50	39	21	2	..
106	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
107	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
108	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
109	..	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
110	..	..	..	..	96	96	95	94	93	92	91	90	88	87	86	84	80	72	53
111	..	..	..	..	100	100	100	100	100	97	96	95	95	95	95	95	95	95	95
112	..	..	..	..	..	..	..	..	..	100	100	100	100	100	100	100	100	100	100

Mixtures of Toluene and Xylene.

% Toluene	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5
% Xylene	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
°C.																			
111	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
112	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
113	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
114	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
115	89	69	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
116	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..
117	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
118	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
119	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
120	96	92	83	73	61	46	27	..	..	1	..	..	..	..	..	..	..	..	..
121	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
122	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
123	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
125	100	96	92	88	83	77	70	60	50	37	..	..	1	..	..	..	..	..	..
126	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
127	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
128	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
129	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..
130	..	..	95	93	91	88	85	80	76	69	64	54	43	30	15	2	..	..	..
132	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
134	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
135	..	..	96	95	95	93	92	90	87	85	85	81	76	71	61	48	30	8	..
136	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
137	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
138	..	..	..	100	96	95	95	94	93	90	90	89	87	86	82	76	68	56	30
139	..	..	..	..	100	..	..	..	..	..	..	..	..	..	..	..	..	..	56
140	..	..	..	..	..	97	96	96	95	95	95	95	94	93	92	91	88	84	84
139	..	..	..	..	..	100	100	..	..	..	..	..	..	..	..	..	95	95	95
142	..	..	..	..	..	..	..	100	100	100	100	100	100	100	100	100	100	100	100

Estimation of sulphur in benzol, toluol, etc. **A measured** quantity of the benzol is mixed with ten times its volume of 90% alcohol (free from sulphur) and burned in a spirit lamp under the trumpet tube of a Gas Referee's Sulphur in Coal Gas apparatus. When the lamp has burned out a further quantity of the alcohol is added and burned to ensure that all sulphur has been consumed. The condenser of the apparatus is washed out and the sulphur after oxidation by bromine is precipitated by $BaCl_2$.

Flash point is taken in the Abel closed test apparatus, a freezing mixture of snow or crushed ice and salt taking the place of the water in the bath in the case of benzol and toluol.

COMMERCIAL PYRIDINE is examined for colour, reaction with cadmium chloride and with Nessler's reagent, for boiling point, miscibility, percentage of water and titration with H_2SO_4.

60's CARBOLIC ACID (*Lowe's test*). 100 ccm. are distilled from an 8 oz. retort having a neck about 15 inches long. No condenser is used and the distillation is so conducted that it lasts about two hours. Reject the first 10 cm. of oil which distills over along with the water, which must not exceed 15 ccm. Then collect the next 62·5 ccm. in a dry cylinder. The 62·5 cc. are well mixed and cooled, stirring with a thermometer all the time. When near the expected crystallising point (usually 60°F.) a small crystal of pure phenol is added, and the temperature is noted when the distillate is crystallised throughout. A Fahrenheit thermometer divided in 1/10° is used. Carbolic acid is also tested for sp. gr. and for solubility in caustic soda solution of sp. gr. 1·100.

CRESYLIC ACID (*liquid carbolic acid*) is tested for sp. gr., for percentage of water, for solubility in 1·100 caustic soda solution and for distilling point. The last test is generally made in a flask with the bulb of the thermometer in the vapour; 95 per cent. should distil between 195° and 205°C. Cresylic acid for soap makers should not give a pink or dark-brown colour with NaOH solution, and should be free from sulphur compounds. H_2S is detected by passing a current of air through the warmed sample and causing the air to impinge on a piece of lead acetate paper.

Hydrocarbon oils in carbolic and cresylic acids may be estimated by mixing 100 ccm. with excess of 20°Tw. NaOH solution and extracting with ether or light petroleum spirit. The extract is washed with a fresh portion of NaOH solution and then the separated ether is evaporated off at a low temperature and the residual oil weighed.

Percentage of phenol and cresol in carbolic and cresylic acid. Fox and Barker describe a method (*J.S.C.I.*, 1917 842-845, and 1918, 265-272), depending on the fact that mixtures of phenol and orthocresol containing over 80% of phenol have a simple freezing point curve. The mixture of tar acids is freed from hydrocarbon oils by solution in caustic soda, extraction with ether or benzol, liberation of the tar acids by addition of H_2SO_4 and the dehydration of the separated acids over $CaCl_2$. The dry acids are then distilled, using a four bulb Young's column, and the fraction to 210°C. collected. This is redistilled in the same apparatus and the phenol is determined in the fraction collected up to 195°C. by determining the freezing point and reference to a curve constructed from the following data. If the fraction contains less than 80% phenol a quantity of pure phenol is added to the distillate and allowed for after taking the freezing point.

FREEZING POINTS.
Mixture of phenol and orthocresol.

% phenol in mixture	100	95	90	85	80
Freezing point °C. ...	40°·2	37°·6	34°·9	32°·2	29°·3

Methods are also given by Weiss and Downs (*J. Ind. Eng. Chem.*, 1917, 569-580, abstracted *J.S.C.I.*, 1917, 863), Knight, Lincoln and others (*J. Ind. Eng. Chem.*, 1918, 9-18, abstracted *J.S.C.I.*, 1918, 85 A).; Skirrow (*J. Ind. Eng. Chem.*, 1917, 1102-1106, abstracted *J.S.C.I.*, 1918, 51 A); Dawson and Mountford (*Chem. Soc. Trans.*, 1918, **113**, 923-944), and Petrie (*J.S.C.I.*, 1919, 132-133 T.)

Meta-cresol is estimated by Raschig's method (see Lunge, *Coal Tar and Ammonia*, 5th edit., p. 803).

CREOSOTE OIL is tested for sp. gr., distilling range, percentage of water, tar acids, naphthalene and the temperature at which it is completely liquid is determined.

100 ccm. are distilled from an 8 oz. retort with the bulb of the thermometer ⅜ in. from the bottom at about two drops per second, noting the percentage of water and the quantity at 315°C. The tar acids are estimated in either the distillate or the original oil (if the latter is not too dirty) by extraction with 20°Tw. NaOH solution. The decrease in the volume of the oil is equal to the quantity of tar acids extracted, or the solution of the latter in the NaOH may be separated, decomposed with dilute acid and the liberated tar acids measured. The percentage of naphthalene is estimated by cooling a known volume or weight of creosote to an agreed

stipulated temperature and keeping the sample at this temperature for an agreed stipulated period. The deposited naphthalene is then rapidly filtered through a Buchner filter and the naphthalene is wrapped in filter paper and squeezed dry in a screw press and weighed. The percentage of naphthalene may also be estimated by Mann's "latent heat point method" (*J.S.C.I.*, 1910, p. 732). The temperature at which the creosote is completely liquid is determined by heating a few ccm. in a test tube till all is liquid, and slowly cooling whilst stirring with a thermometer, the point at which crystals first begin to form being recorded.

Sometimes the per cent. of material insoluble in benzol has to be estimated. This is done by diluting a known quantity of creosote with benzol, filtering off any insoluble matter and washing, drying and weighing in the ordinary way.

Creosote oil for fuel purposes is also tested for its flash point and burning point, its sulphur content and its calorific value. See section on Fuels and Illuminants.

CREOSOTE SALTS AND NAPHTHALENE are generally tested for liquefying point, water, impurities insoluble in benzol and sometimes for distillation point.

The liquefying point is taken by melting, say, 100—200 grammes of the sample in a small enamelled saucepan and heating up to 120°C. to ensure the elimination of water, and then cooling slowly, stirring with a thermometer. When solidification sets in the mercury will rise slightly and remain steady for some little time, and the highest point of this after-rise is the temperature of liquefaction. Water is estimated by distilling about 200 grammes from a retort until water ceases to come over. The distillate is collected in a graduated cylinder containing a few ccm. of naphtha to dissolve the naphthalene which comes over with the water. Separation of the water and naphtha may be facilitated by the addition of about 10% pure NaCl to the water.

PITCH.

Twisting point. A rod of pitch $\frac{1}{2}$ in. square and $1\frac{1}{2}$ to 2 ins. long, moulded or cut from the sample, is suspended by a string in a beaker of water. A thermometer is also suspended so that the bulb is close to and level with the sample. The water is heated so that the temperature is raised at the rate of 1°C. per minute, and the rod is taken out at intervals and twisted round by hand. The temperature at which it can be twisted round once or twice without breaking is taken as the twisting point.

Volatile matter. 1 gramme of the powdered sample is

heated in a platinum crucible, with the cover on, over a bunsen burner with a flame 7in. long for 3 minutes; the crucible and contents is then heated over the blowpipe for 3 minutes longer, and weighed after cooling in the desiccator. The loss in weight represents the volatile matter.

Ash is determined either in the coke left from the volatile matter or in a fresh portion of the sample by roasting in a dish until all carbonaceous matter has been burned away.

Free carbon is estimated similarly to the free carbon in crude tar.

Considerable information as to the nature of pitch may be obtained from a study of the action of solvents, see Mansbridge (*J.S.C.I.*, 1918, 182 T.).

General notes and precautions. When comparing distilling points of various samples care must be taken that the conditions of the tests are the same in each case. The best way of comparing the boiling range of two samples of similar substances is to plot out a boiling point curve for each.

REFERENCES.

Lunge. *Coal Tar and Ammonia.*
Lunge. *Technical Methods of Chemical Analysis*, vol. iii.
Warnes. *Coal Tar Distillation.*
Spielmann. *Some Constituents of Coal Tar and their Properties.*
J. M. Weiss, S. R. Church and others. *Methods of Analysis of the Coal Tar Industry.* Pub. by the Barrett Company, New York.
Allen's *Commercial Organic Analysis.*

A good deal of work has been published during the last four or five years in the *Journal of Industrial and Engineering Chemistry* and in the *Journal of the Society of Chemical Industry*, and reference to recent volumes of these journals will well repay the trouble.

INTERMEDIATE PRODUCTS.

Pure Benzene and Pure Toluene.

95 per cent. of a commercially pure sample should distil within 0.8°C. Conc. H_2SO_4 should give at the most a pale yellow colour.

Detection of Thiophen.

A crystal of isatin is added to a small amount of concentrated sulphuric acid, and then a few drops of the sample added. The production of an intense blue colour indicates the presence of thiophen.

Detection of Carbon Disulphide.

Four or five drops of phenylhydrazine are added to 10 cc. of the sample, the mixture shaken and allowed to stand for an hour. Crystals are obtained in presence of even 0.03 per cent. of carbon disulphide.

Detection of Phenol.

After warming with Methyl violet, the filtrate should be absolutely colourless.

Naphthalene.

Chemically pure samples should solidify at 79.6–79.8°C., boil at 217–218°C., and should give a colourless clear solution in light petroleum. The sample should not become yellow on exposure to air; this is ascertained by exposure to pure, concentrated nitric acid in a bell-jar, when the sample should remain colourless for two hours. Phenols may be detected by extracting with caustic soda, acidifying the extract with hydrochloric acid, and adding bromine water, when tribromo-phenols are produced.

Naphthalene can be quantitatively determined as picrate in absence of certain other hydrocarbons (Küster).

Anthracene.

Luck's method ("Höchst test") for the valuation of anthracene is as follows :

1 grm. of the sample is weighed into a 500 cc. flask, 45 cc. of *pure* glacial acetic acid added, the flask connected to a reflux condenser 75 cm. long, and the contents raised to the boiling point. A freshly prepared solution of 15 grm. of chromic acid crystals in 10 cc. of *pure* glacial acetic acid and 10 cc. of water is added drop by drop over a period of 2 hours. After boiling for a further 2 hours, the liquid is allowed to stand for 12 hours, and 400 cc. of water are added. After standing for a further period of 3 hours the precipitate is filtered off, washed with cold, distilled water,

then with slightly alkaline, boiling water until the filtrate remains clear on acidifying, and finally with pure boiling water until the filtrate is neutral. The crude anthraquinone is rinsed into a porcelain dish, and dried at 100°C. 10 grm. of slightly fuming sulphuric acid are added, the dish heated in an air-oven at 112°C. for ten minutes and then allowed to stand in a damp place for 12 hours to absorb water. The liquid is then rinsed into a large evaporating basin by means of 200 cc. of water, the mixture allowed to cool, and the pure anthraquinone filtered off, washed and dried as above.

Equivalent weights of Anthraquinone and Anthracene

Anthra-quinone.	Anthra-cene.	Anthra-quinone.	Anthra-cene.	Anthra-quinone.	Anthra-cene.	Anthra-quinone.	Anthra-cene.
1	0.86	26	22.26	51	43.66	76	65.06
2	1.71	27	23.11	52	44.51	77	65.91
3	2.57	28	23.97	53	45.37	78	66.77
4	3.42	29	24.82	54	46.22	79	67.62
5	4.28	30	25.68	55	47.08	80	68.48
6	5.14	31	26.54	56	47,94	81	69.34
7	5.99	32	27.39	57	48.79	82	70.19
8	6.85	33	28.25	58	49.65	83	71.05
9	7.70	34	29.10	59	50.50	84	71.90
10	8.56	35	29.96	60	F1.36	85	72.76
11	9.42	36	30.82	61	52.22	86	73.62
12	10.27	37	31.67	62	53.07	87	74.47
13	11.13	38	32.53	63	53.93	88	75.33
14	11.98	39	33.38	64	54.78	89	76.18
15	12.84	40	34.24	65	55.64	90	77.03
16	13.70	41	35.10	66	56,50	91	77.89
17	14.55	42	35.95	67	57.35	92	78.74
18	15.41	43	36.81	68	58.21	93	79.60
19	16.26	44	37.66	69	59.06	94	80.45
20	17.12	45	38.52	70	59.92	95	81.31
21	17.98	46	39.38	71	60.78	96	82.17
22	18.83	47	40.23	72	61.63	97	83,02
23	19.69	48	41.09	73	62.49	98	83.88
24	20.54	49	41.94	74	63.34	99	84.73
25	21.40	50	42.80	75	64.28	100	85.59

Aniline.

> " Aniline oil for red," B.P. 181—183°C.,
> Sp. Gr. 1·0265—1·0267 at 15°C.
> " Aniline oil for blue," B.P. 182—198°C.,
> Sp. Gr. 1·006—1·1009 at 15°C.

Aniline and other primary amines are determined as follows : A standard solution of sodium sulphanilate

$$(NH_2.C_6H_4.SO_3Na + 2H_2O)$$
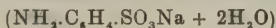
containing about 15 grm. per litre is prepared. 50 cc. are diluted to about 250 cc. with water, 10 cc. of hydrochloric acid added and a solution of sodium nitrite containing about 25 grm. per litre is added until a drop of the solution immediately turns cadmium iodide starch paper blue. The standardised sodium nitrite solution is used for titrating the acidified aniline cooled with ice.

SOLUBILITY OF ANILINE (Alexeeff).

°C.	100 grm. water dissolve grm. aniline.	°C.	100 grm. aniline dissolve grm. water.
16	3.1	8	4.6
56	3.5	25	4.98
82	5.1	39	5.43
		68	6.04

Dimethylaniline.

Aniline is detected as sulphate by addition of dilute sulphuric acid.

Methylaniline is detected by allowing 10 cc. of the sample, contained in a wide test-tube, and 3 cc. of acetic anhydride, contained in a narrower test-tube, to stand in a beaker of water for some time, noting the temperature of the samples, and then observing the maximum temperature attained on rapidly adding the acetic anhydride with stirring. Each 1°C. rise in temperature corresponds to 0·5 per cent. of methylaniline. (A correction is necessary, as the temperature of pure dimethyl-aniline is lowered 1°C. by this treatment.)

Specific Gravity of Mixtures of *o-* and *p-* Toluidine.

Sp. Gr. at 15°C. (water at 15°C.=1)	% *o*-Toluidine.	Sp. Gr. at 15°C. (water at 15° C.=1)	% *o*-Toluidine.
1.0037	100	1.0004	72.5
36	99	03	72
35	98	02	71
34	97	01	70
33	96	00	69
32	95	0.9999	68.5
31	94	98	68
30	93.5	97	67
29	92.5	96	66.5
28	91.5	95	65.5
27	91	94	65
26	90	93	64
25	89.5	92	63
24	88.5	91	62
23	88	90	61.5
22	87	89	61
21	86.5	88	60
20	86	87	59
19	85	86	58.5
18	84.5	85	58
17	83.5	84	57.5
16	82.5	83	56.5
15	82	82	56
14	81	81	55
13	80	80	54.5
12	79.5	79	54
11	78.5	78	53
10	77.5	77	52.5
09	77	76	51.5
08	76	75	51
07	75	74	50
06	74		
05	73		

Sp. Gr. at 20°C. (water at 15°C.=1)	% o-Toluidine.	Sp. Gr. at 20°C. (water at 15°C.=1)	% o-Toluidine.
0.9939	50	0.9932	45
38	49.5	31	44.5
37	48.5	30	44
36	48	29	43
35	47.5	28	42
34	46.5	27	41
33	46	26	40

Commercial Names of Intermediate Products.

(See " Nomenclature of Organic Compounds.")

Anthranilic acid. o-Aminobenzoic acid.

Ketone base. Tetramethyldiaminobenzophenone.

Leucotrope. Dimethylaniline and benzyl chloride condensed to quaternary ammonium chloride.

Naphthol AS. Anilide of β-hydroxynaphthoic acid.

Nitroso base. p-Nitrosodimethylaniline.

Rongalite. Formaldehyde sodium sulphoxylate,
$$CH_2(OH).OSONa.2H_2O.$$

Dihydroxyanthraquinones.

Alizarin,	1 : 2-	dihydroxyanthraquinone
Purpuroxanthin,	1 : 3-	,, ,,
Quinizarin,	1 : 4-	,, ,,
Anthrarufin,	1 : 5-	,, ,,
m-*Dihydroxyanthraquinone,*	1 : 7-	,, ,,
Chrysazin,	1 : 8-	,, ,,
Histazarin,	2 : 3-	,, ,,
Anthraflavic acid,	2 : 6-	,, ,,
Isoanthraflavic acid,	2 ; 7-	,, ,,

Trihydroxyanthraquinones.

Anthragallol,	1 : 2 : 3-	trihydroxyanthraquinone
Purpurin,	1 : 2 : 4-	,, ,,
Oxyanthrarufin,	1 : 2 : 5-	,, ,,
Flavopurpurin,	1 : 2 : 6-	,, ,,
Isopurpurin	1 : 2 : 7-	,, ,,
Oxychrysazin,	1 : 2 : 8-	,, ,,

Sulphonic Acids

γ-Acid. 2 : 8-Aminonaphthol-6-sulphonic acid.

δ-Acid. 2-Naphthol-3-7-disulphonic acid.

ε-Acid. 1-Naphthol-3 : 8-disulphonic acid.

Amino G salt. 2-Naphthylamine-6 : 8-disulphonic acid, sodium salt.

Amino R salt. 2-Naphthylamine-3 : 6-disulphonic acid, sodium salt.

Aminonaphthol disulphonic acid B (1 : 8 : 3 : 5).

Aminonaphthol disulphonic acid 2 S (1 : 8 : 2 : 4).

Badische acid. 2-Naphthylamine-8-sulphonic acid.

Bayer acid. See *Crocein acid.*

Brönner's acid. 2-Naphthylamine-6-sulphonic acid.

Chicago acid. See *2S acid.*

Chromotrope acid. 1 : 8-Dihydroxynaphthalene-3 : 6-sulphonic acid.

Cleve's acids. 1 : 6-and 1 : 7-Naphthylamine monosulphonic acids.

Crocein acid. 2-Naphthol-8-sulphonic acid.

Dahl's acid II. 1-Naphthylamine-4 : 6-disulphonic acid.

Dahl's acid III. 1-Naphthylamine-4 : 7-disulphonic acid.

Dihydroxynaphthalene sulphonic acid S (1 : 8 : 4).

Dihydroxynaphthalene disulphonic acid K (1 : 8 : 4 : 6).

Eikonogen. 1 : 2-Aminonaphthol-6-sulphonic acid ; sodium salt.

F acid. 2-Naphthol-7-sulphonic acid.

G acid. 2-Naphthol-6 : 8-disulphonic acid.

H acid. 1 : 8-Aminonaphthol-3 : 6-disulphonic acid.

J acid. 2 ; 5-Aminonaphthol-7-sulphonic acid.

K acid. 1 : 8-Aminonaphthol-4 : 6-disulphonic acid.

L (Laurent's) acid. 1-Naphthylamine-5-sulphonic acid.

Metanilic acid. Aniline-*m*-sulphonic acid.

Naphthionic acid. 1-Naphthylamine-4-sulphonic acid.

ortho-*Naphthionic acid.* 1-Naphthylamine-2-sulphonic acid.

α-Naphthol sulphonic acid C (1 : 5).

Naphthylamine disulphonic acid Sch. (1 : 4 : 8).

Nigrotic acid. Dihydroxysulphonaphthoic acid (2 : 8 : 3 : 6).

N.W. (Nevile and Winther's) acid. 1-Naphthol-4-sulphonic acid.

Peri-acid. 1-Naphthylamine-8-sulphonic acid.

Phenyl Peri-acid. 1-Phenylnaphthylamine-8-sulphonic acid.

R acid. 2-Naphthol-3 : 6-disulphonic acid.

2R acid. 2 : 8-Aminonaphthol-3 : 6-disulphonic acid.

S acid. 1 : 8-Aminonaphthol-4-sulphonic acid.

2S acid. 1 : 8-Dihydroxynaphthalene-2 : 4-disulphonic acid.

Schäffer's acid. 2-Naphthol-6-sulphonic acid.

Schöllkopf s acid. 1-Naphthol-4 : 8-disulphonic acid.

Sulphanilic acid. Aniline-*p*-sulphonic acid.

Tolyl Peri-acid. 1-Tolylnaphthylamine-8-sulphonic acid.

Formation of Azo-compounds.

Rules for Coupling with Diazo-compounds.

With Benzene Derivatives:

Coupling occurs in *para*-position to the OH or NH_2 group, if free; otherwise in *ortho*-position, if free. If both *ortho*- and *para*-positions are occupied, coupling does not take place. (Exceptions to this rule are known).

With a-Derivatives of Naphthalene:

Coupling occurs in *para*- (a) position to the OH or NH_2 group provided that this position and the adjacent β-position are *both* free; otherwise in *ortho*-(β) position, if free. In case this last-named position is occupied, coupling does not take place.

With β-Derivatives of Naphthalene:

Coupling occurs in a-position adjacent to the OH or NH_2 group if free, and in no other position.

The Composition of Synthetic Dyestuffs

With Some Notes on their Preparation.

Acetine blue. Soln. of Induline in acetine.

Acid Alizarin black R. Nitro-*o*-aminophenol sulphonic acid diazotised + β-naphthol.

Acid Alizarin blue BB, GR. Sulphonic acids of *Anthracene blue WR.*

Acid blue 6G. See *Cyanol.*

Acid green. See *Light green SF.*

Acid Magenta. Sulphonated Magenta; ammonium salt.

Acid violet 4BN. Ketone base condensed with benzylmethylaniline; sulphonated; oxidised.

$$HO.C \begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4.N(CH_3)_2 \\ C_6H_4.N{<}^{CH_3}_{CH_2.C_6H_4.SO_3Na} \end{matrix}$$
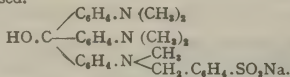
Acid violet 6B. Disulphonic acid of dimethyldiethyldibenzylpararosaniline.

Acid violet 6BN. Ketone base condensed with *p*-tolyl-*m*-ethoxyphenylamine sulphonated; oxidised.

Acid violet 7B. From *p*-diethylaminobenzoyl chloride and methyldiphenylamine

$$C \begin{matrix} C_6H_4.N(CH_3).C_6H_4.SO_3Na \\ C_6H_4.N(CH_3).C_6H_4.SO_3 \\ C_6H_4 : N(CH_3)_2 \end{matrix} ----|$$
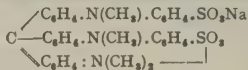
Acid yellow GR. See *Fast yellow G.*

Acid yellow C. See *Naphthol yellow S.*

Acid yellow D. See *Diphenylamine orange.*

Acridine orange R extra. Condensation of benzaldehyde with *m*-aminodimethylaniline; elimination of ammonia; oxidation.

$$(CH_3)_2N.C_6H_3 \begin{matrix} {>}^N_{C}{<} \end{matrix} C_6H_3.N(CH_3)_2$$

$$\underset{C_6H_5}{|}$$
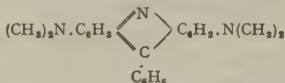
Acridine red B. Oxidation of *Pyronine G* with permanganate.

$$(CH_3)_2N.C_6H_3 \begin{matrix} Cl \\ {>}^O_{CH}{<} \end{matrix} C_6H_3.N(CH_3)_2$$
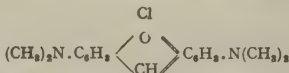
Acridine yellow. Action of formaldehyde on *m*-toluylenediamine; oxidation with ferric chloride.

$$(CH_3)_2N \atop CH_3 {>} C_6H_2 \begin{matrix} {>}^N_{CH}{<} \end{matrix} C_6H_2 {<}^{NH_2}_{CH_3}$$
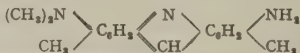
Afghan yellow. See *Curcumine S.*

Algol blue CF. Chloro-derivative of indanthrene.

Algol blue 3G. A dihydroxy-indanthrene.

Algol blue 3R. Dibenzoyldiaminoanthrarufin.

Algol bordeaux 3B. An anthraquinoneimide.

Algol Brilliant orange FR. Benzoyl-1 : 2 : 4-triaminoanthraquinone.

Algol Brilliant red 2B. 1 : 5-Dibenzoyldiamino-4-hydroxy-anthraquinone.

Algol Brilliant violet 2B. See *Algol blue 3R.*

Algol green B. Dibromo-diamino-indanthrene.

Algol grey B. Nitration of trianthramide obtained by condensing 1 : 5-diamino anthraquinone with two molecules of α-chloro-anthraquinone and reduction of the product with an alkali sulphide.

Algol olive R. Action of chlorsulphonic acid on dibenzoyldiamino-anthraquinone.

Algol orange R. An anthraquinoneimide.

Algol pink R. Benzoyl-4-amino-1-hydroxy-anthraquinone.

Algol red B.
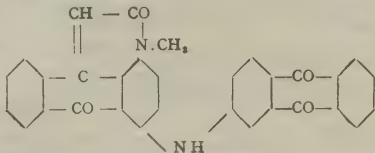
Algol red 5G. Dibenzoyl-1 : 4-diamino-anthraquinone.

Algol red R extra. Dibenzoyl-1 : 5-diamino-8-hydroxy-anthraquinone.

Algol scarlet G. Benzoyl-1-amino-4-methoxy-anthraquinone.

Algol violet B. Benzoyl-amino-4 : 5 : 8-trihydroxy-anthraquinone.

Algol yellow 3G. Succinyl-(1-amino-anthraquinone)$_2$.

Algol yellow R. Dibenzoyl-1 : 5-diamino-anthraquinone.

Algol yellow WG. Benzoyl-1-amino-anthraquinone.

Alizarin. Fusion of anthraquinone-β-sulphonic acid with caustic alkalies.

$$C_6H_4 \diagdown \!\!\!\!\! \begin{array}{c} CO \\ CO \end{array} \!\!\!\!\! \diagup C_6H_2 \diagdown \!\!\!\!\! \begin{array}{c} OH\ (1) \\ OH\ (2) \end{array}$$
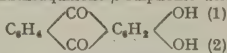
Alizarin OG and *OR.* See *Alizarin orange.*

Alizarin GI, RG, SDG, X. See *Flavopurpurin.*

Alizarin SX, GD. See *Anthrapurpurin.*

Alizarin S. Sodium salt of Alizarin sulphonic acid.

Alizarin Astrole.

$$C_6H_4 \diagdown \!\!\!\!\! \begin{array}{c} CO \\ CO \end{array} \!\!\!\!\! \diagup C_6H_2 \diagdown \!\!\!\!\! \begin{array}{c} NH.C_6H_2(CH_3).SO_3H\ (1) \\ NH.CH_3\ (4) \end{array}$$
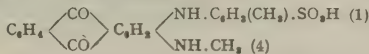
Alizarin blacks. 1 : 2-Dihydroxynaphthaquinone (Naphthazarin)+NaHSO$_3$.

Alizarin blue. β-Nitroalizarin heated with glycerin and sulphuric acid. Dihydroxyanthraquinolinequinone.

$$C_6H_4 \diagdown \!\!\!\!\! \begin{array}{c} CO \\ CO \end{array} \!\!\!\!\! \diagup C_6(OH)_2 \diagdown \!\!\!\!\! \begin{array}{c} N:CH \\ CH:CH \end{array}$$
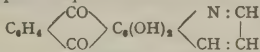
Alizarin blue S. Sodium bisulphite compound of *Alizarin blue.*

Alizarin blue-green. Sulphonic acid of a trihydroxyanthraquinolinequinone.

Alizarin bordeaux. 1 : 2 : 5 : 8-Tetrahydroxyanthraquinone.

Alizarin Celestole. Action of formaldehyde on *Alizarin Saphirole B.*

Alizarin Cyanine. 1 : 2 : 4 : 5 : 8-pentahydroxyanthraquinone.

Alizarin Cyanine green E, G, K. Sulphonation of 1 : 4 di-p-toluidino anthraquinone.

Alizarin indigo blue S, SW. Action of sulphuric acid at 200° C. on Alizarin green. Mainly :

Alizarin Irisole.

$$C_6H_4 \begin{array}{c} CO \\ CO \end{array} C_6H_3 \begin{array}{c} OH\ (1) \\ NH.C_6H_3(CH_3).SO_3H\ (4) \end{array}$$
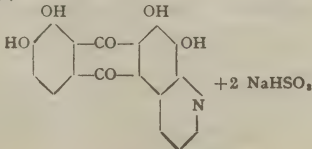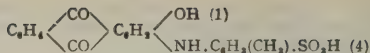
Alizarin maroon. Principally α- and β-aminoalizarin.
Alizarin orange. 20 per cent. paste of β-nitroalizarin.
Alizarin Pure blue. See *Alizarin Sky blue.*
Alizarin red S. Sodium salt of Alizarin monosulphonic acid.
Alizarin Saphirole B.
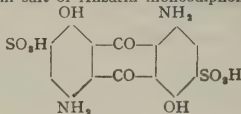
Alizarin Sky blue. 2 : 4 - Dibromo - 1 - amino - anthraquinone heated with *p*-toluidine ; sulphonation.

$$C_6H_4 \begin{array}{c} CO \\ CO \end{array} C_6HBr(3) \begin{array}{c} NH.C_6H_3(CH_3).SO_3H\ (1) \\ NH_2\ (4) \end{array}$$
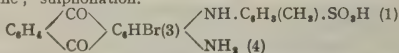
Alizarin Viridine DG, FF. *Alizarin bordeaux* heated with *p*-toluidine sulphonation.

$$\begin{array}{c} (8)\ SO_3H.C_6H_3(CH_3).NH \\ (5)\ SO_3H.C_6H_3(CH_3).NH \end{array} C_6H_2 \begin{array}{c} CO \\ CO \end{array} C_6H_3 \begin{array}{c} OH\ (1) \\ OH\ (2) \end{array}$$
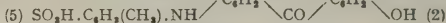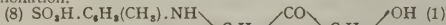
Alizarin yellow A. Trihydroxybenzophenone. $C_6H_5.CO.C_6H_2(OH)_3$.
Alizarin yellow C. Trihydroxyacetophenone. $CH_3.CO.C_6H_2(OH)_3$.
Alizarin yellow FS. Magenta diazotised + salicylic acid.
Alizarin yellow GG. *m*-Nitraniline diazotised + salicylic acid.
Alizarin yellow R. *p*-Nitraniline diazotised + salicylic acid.
Alizarin violet. See *Gallein.*
Alkali blue. Sodium salt of diphenylrosaniline monosulphonic acid.
Alkali blue XG. Sodium salt of β-naphthylpararosaniline monosulphonic acid.
Alkali brown R. Primuline diazotised + *m*-phenylenediamine.
Alkali yellow. See *Cotton yellow R.*
Alkali yellow R.
$$Benzidine \begin{array}{c} salicylic\ acid. \\ dehydrothiotoluidine\ sulphonic\ acid. \end{array}$$
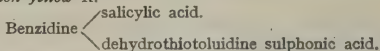
Alkali violet 6B. Sodium salt of tetraethylmonomethylphenylpararosaniline monosulphonic acid.

$$HO.C \begin{array}{c} C_6H_4.N(C_2H_5)_2 \\ C_6H_4.N(C_2H_5)_2 \\ C_6H_4.N \begin{array}{c} CH_3 \\ C_6H_4.SO_3Na \end{array} \end{array}$$
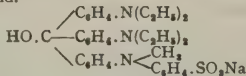
Alsace green. Dinitrosoresorcinol ; iron salt.
Amaranth. Naphthionic acid diazotised + R salt
Amethyst violet. Tetraethyl-phenosafranine.
Aniline black. Oxidation of aniline (*o*-toluidine diphenylamine) hydrochloride on the fibre by means of chlorates in presence of a copper or vanadium salt, by chromates, or by air in presence of a copper salt and *p*-phenylene-diamine or *p*-aminophenol. " Aged " or chlorate black.
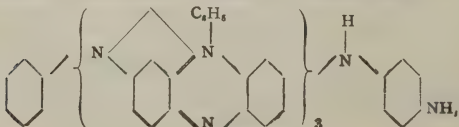
Aniline blue (spirit-soluble). Mixture of triphenylpararosaniline and diphenyl-rosaniline hydrochlorides.

Aniline brown. See **Bismarck brown.**

Aniline pink. See **Safranine.**

Aniline purple. See **Mauveine.**

Aniline red. See **Magenta.**

Aniline violets. Alkylated Rosanilines.

Aniline yellow. Amidoazobenzene hydrochloride.

Anisolines. Esters of Rhodamines.

Anthracene blue WR. 1 : 5-Dinitroanthraquinone heated with fuming H_2SO_4. 1 : 3 : 4 : 5 : 7 : 8-Hexahydroxyanthraquinone.

Anthracene blue WG. Above dyestuff heated with caustic soda and ammonia under pressure.

Anthracene blue WGG. 1 : 5-Dinitroanthraquinone heated with fuming H_2SO_4, sulphur and boric acid.

Anthracene brown. See **Anthragallol.**

Anthracene Chrome black. Amino R salt diazotised + β-naphthol.

Anthracene green. See **Cœrulein.**

Anthracene red. o-Nitrobenzidine tetrazotised $\left\{\begin{array}{l}\text{salicylic acid.}\\\text{N.W. acid.}\end{array}\right.$

Anthracene violet. See **Gallein.**

Anthracite black. Dahl's acid II. diazotised + α-naphthylamine, diazotised + diphenyl-m-phenylenediamine.

Anthracyanines. Derived from Gallocyanines.

Anthraflavone. Oxidation of 2-methylanthraquinone. Diphthaloylstilbene.

$$C_6H_4 \underset{CO}{\overset{CO}{\big\langle}} C_6H_2 . CH : CH . C_6H_3 \underset{CO}{\overset{CO}{\big\rangle}} C_6H_4$$

Anthragallol. 1 : 2 : 3-Trihydroxyanthraquinone.

Anthrapurpurin. 1 : 2 : 7-Trihydroxyanthraquinone.

Anthraquinone black. 1 : 5-Dinitronaphthalene heated with polysulphide until soluble in water.

Anthraquinone blue. 2 : 4 : 6 : 8-Tetrabromo-1 : 5-diaminoanthraquinone heated with p-toluidine ; sulphonation.

$$(8)\ SO_3H.C_6H_3(CH_3).NH\underset{(5)\ NH_2}{\overset{}{\big\langle}}C_6HBr(6)\underset{CO}{\overset{CO}{\big\langle}}C_6HBr(2)\overset{NH_2\ (1)}{\underset{NH.C_6H_3\,(CH_3)}{\big\rangle}}$$
$$.SO_3H\ (4)$$

Anthraquinone violet.

$$NH-C_6H_3(CH_3).SO_3H$$

(structure)
—CO—
—CO—

$$SO_3H.(CH_3)C_6H_3-NH$$
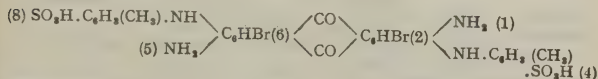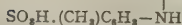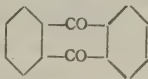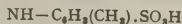
Anthrarufin. 1 : 5-Dihydroxyanthraquinone.

Apollo red. See **Orchil substitute 3VN.**

Aposafranine. Diazotised Safranine boiled with alcohol.

Atlas red. Primuline diazotised + m-toluylenediamine.

Auramine. Ammonia passed into a fused mixture of dimethyldiaminodiphenyl-methane and sulphur.

$$(CH_3)_2N.C_6H_4.\underset{\overset{\|}{H}}{C}.C_6H_4.N(CH_3)_2,\quad \underset{H\ Cl}{\overset{A}{}}$$

Auramine G. (o) CH₃ , (CH₃)NH $C_6H_3.C.C_6H_3$, CH₃ (o), NH(CH₃)

$$\underset{NH}{\|}$$
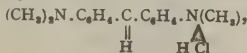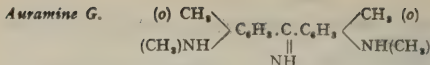
Aurin. Pararosolic acid.

$$C\underset{\diagdown C_6H_4=O}{\overset{\diagup C_6H_4OH}{-C_6H_4OH}}$$
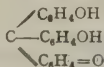
Auronal black. p-Aminodinitrodiphenylamine treated with alkali polysulphide.

Azalein. Aniline heated with mercuric nitrate. See *Magenta.*

Azarine S. Aminodichlorophenol diazotised + β-naphthol; product treated with ammonium bisulphite.

$$C_6H_2Cl_2(OH).NH.N\underset{\diagdown C_{10}H_6.OH\,(\beta)}{\overset{\diagup SO_3NH_4}{}}$$
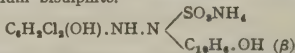
Azidine Fast scarlets. Derivatives of the complex urea obtained by passing carbonyl chloride into a mixture of one molecule of m-toluylenediamine. 4-sulphonic acid and two molecules of J acid.

Azo black-blue. Tolidine tetrazotised ⟨ H acid / m-hydroxydiphenylamine.

Azo blue. Tolidine tetrazotised + 2 mols. N.W. acid ; sodium salt.

Azo bordeaux.

Tolidine tetrazotised ⟨ aminophenol sulphonic acid. / m-phenylenediamine + diazotised naphthionic acid.

Azo carmine. Phenylrosinduline disulphonic acid.

Azochromine. Aminophenol diazotised + pyrogallol.

Azo cochineal. o-Anisidine diazotised + Schöllkopf's acid.

Azococcine 2R. Xylidine diazotised + N.W. acid ; sodium salt.

Azocoralline. p-Aminoacetanilide diazotised + R acid.

Azocorinth. Naphthionic acid diazotised ⟩ Resorcinol.

Tolidine tetrazotised ⟨ Aminophenol sulphonic acid.

Azoeosin. o-Anisidine diazotised + N.W. acid.

Azoflavine S. Highly nitrated Diphenylamine orange.

Azo green. m-aminotetramethyl-p-diaminotriphenylmethane diazotised + salicylic acid, and oxidation.

Azo Magenta G. Sulphanilic acid diazotised + S acid.

Azo mauve. Tolidine tetrazotised ⟨ H acid. / α-naphthylamine (alkaline soln).

Azophenosafranines. Asymmetrical Safranines.

Azophosphine G.O. m-Aminophenyltrimethylammonium chloride diazotised + resorcinol.

Azorubine S. See *Amaranth.*

Azo violet. Dianisidine tetrazotised ⟨ naphthionic acid / N.W. acid ⟩ sodium salt.

Azo yellow. Nitrated Diphenylamine orange.

Aaxle blue R. Nitrosodimethylaniline condensed with 2 : 7-ditolylnaphthylene-diamine.

$$(CH_3)_2N.C_6H_3\underset{\diagdown N\diagup}{\overset{\diagup N\diagdown}{}}CH_{10}H_6.NH(C_6H_4.CH_3$$

$$\underset{Cl\,C_6H_4.CH_3}{\overset{\wedge}{}}$$
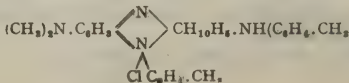
Bavarian blue. See *Diphenylamine blue.*

Benzaldehyde green. See *Malachite green.*

Benzo Azurine G. Dianisidine tetrazotised + 2 mols. N.W. acid.

Benzo black-blue G.

Benzidine disulphonic acid tetrazotised $\Big\langle$ α-naphthylamine, diazotised + N.W. acid.
N.W. acid.

Benzo black-blue R.

Tolidine tetrazotised $\Big\langle$ N.W. acid.
α-naphthylamine, diazotised + N.W. acid.

Benzo blue BB. Benzidine tetrazotised + 2 mols. H acid (in alkaline soln.).

Benzo Brilliant blue. See *Soluble blue XG.*

Benzo brown. Naphthionic acid diazotised + *Bismarck brown.*

Benzo brown G. Sulphanilic acid $\rangle$ *m*-phenylenediamine.

m-Phenylenediamine $\rangle$ *m*-phenylenediamine.
Sulphanilic acid $\nearrow$

Benzo Fast scarlets. Diazobenzene, &c.+ complex urea obtained by the action of carbonyl chloride on 2 mols. J acid.

Benzoflavine. Diaminodimethylphenylacridine hydrochloride.

$$\begin{array}{c} NH_3 \quad \diagup\!\!\!\diagdown \; =N— \; \diagup\!\!\!\diagdown \; NH_3 \\ CH_3 \quad \diagdown\!\!\!\diagup \; =C— \; \diagdown\!\!\!\diagup \; CH_3 \\ \qquad\qquad C_6H_5 \end{array}$$
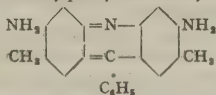
Benzo indigo blue.

Tolidine tetrazotised $\Big\langle$ dihydroxynaphthalene sulphonic acid S.
α-naphthylamine, diazotised + dihydroxynaphthalene sulphonic acid S.

Benzo olive.

Benzidine tetrazotised $\Big\langle$ salicylic acid.
α-naphthylamine, diazotised + H acid.

Benzo orange R.

Benzidine tetrazotised $\Big\langle$ salicylic acid.
naphthionic acid.

Benzo Pure blue. See *Diamine Pure blue.*

Benzopurpurine B. Tolidine tetrazotised + 2 mols. Brönner's acid.

Benzopurpurine 4B. Tolidine tetrazotised + 2 mols. naphthionic acid.

Benzopurpurine 6B. Tolidine tetrazotised + 2 mols. L acid.

Benzopurpurine 10B. Dianisidine tetrazotised + 2 mols. naphthionic acid.

Benzyl violet. Action of benzyl chloride on *Methyl violet B.*

$$C \begin{cases} C_6H_4.N \diagup\!\!\! CH_3 \\ \qquad\qquad \diagdown CH_3.C_6H_5 \\ C_6H_4.N(CH_3)_2 \\ C_6H_4 : N(CH_3)_2.Cl \end{cases}$$
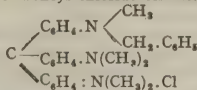
Biebrich Patent black 4NA. Naphthionic acid diazotised + Cleve's acids diazotised + α-naphthylamine.

Biebrich scarlet. Aminoazobenzene disulphonic acid diazotised + β-naphthol.

Bindschedler's green. Oxidation of dimethyl-*p*-phenylenediamine and dimethylaniline. Tetramethylindamine.
$(CH_3)_2N.C_6H_4.N : C_6H_4 : N(CH_3)_2.Cl$

Bismarck brown. *m*-Phenylenediamine tetrazotised + 2 mols. *m*-phenylenediamine (or *m*-toluylenediamine). Mainly

$$C_6H_4 \diagdown\!\!\! {}^{N : N.C_6H_3(NH_2)_2}_{N : N.C_6H_3(NH_2)_2}$$
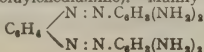
Bordeaux B. α-Naphthylamine diazotised + R acid.

Bordeaux G. Aminoazotoluene sulphonic acid diazotised + Schäffer's acid.

$$CH_3.C_6H_3 \begin{array}{l} N:N.C_6H_4 \\ SO_3Na \end{array} \begin{array}{l} CH_3 \\ N:N.C_{10}H_5 \end{array} \begin{array}{l} OH\ (2) \\ SO_3Na\ (6) \end{array}$$
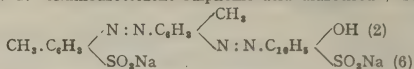
Bordeaux S. Naphthol acid diazotised + R acid.

Brilliant Alizarin blue G, R. β-Naphthoquinone-α-sulphonic acid or -2 : 5-disulphonic acid and dimethyl-*p*-phenylenediamine thiosulphonic acid.

$$(CH_3)_2N.C_6H_3 \begin{array}{l} N \\ S \end{array} C_{10}H_5 \begin{array}{l} OH \\ O \end{array}$$
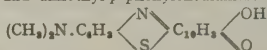
Brilliant Azurine 5G. Dianisidine diazotised + 2 mols. dihydroxynaphthalene sulphonic acid S.

Brilliant Congo G. Benzidine tetrazotised + amino R salt, diazotised + Brönner's acid.

Brilliant Congo R. Tolidine tetrazotised + amino R salt, diazotised + Brönner's acid.

Brilliant Congo 2R. Tolidine tetrazotised $\begin{array}{l} amino\ R\ salt. \\ F\ acid. \end{array}$

Brilliant Cotton blue. See *Helvetia blue.*

Brilliant Crocein. Aminoazobenzene diazotised + G acid.

Brilliant green. Tetraethyldiaminofuchsonimonium sulphate, or ZnCl₂ double salt.

Brilliant orange G. Aniline diazotised + Schäffer's acid.

Brilliant orange O. Toluidine diazotised + Schäffer's acid.

Brilliant orange R. Xylidine diazotised + Schäffer's acid.

Brilliant ponceau 4R. Brönner's acid diazotised + N.W. acid.

Brilliant ponceau 5R. Naphthionic acid diazotised + G acid.

Brilliant Purpurine R. Tolidine tetrazotised $\begin{array}{l} amino\ R\ salt. \\ naphthionic\ acid. \end{array}$

Buffalo Rubine. α-Naphthylamine diazotised + Schöllkopf's acid.

Cachou de Laval. Organic matter (sawdust, &c.) fused with sodium polysulphide.

Capri blue. Condensation of nitrosodimethylaniline with dimethyl-*m*-amino cresol.

Carmoisine B. Naphthionic and diazotised + N.W. acid.

Carnotine. See *Primuline.*

Cattù Italiano. See *Cachou de Laval.*

Cerise. Mixture of *Magenta* and *Phosphine.*

Cerotine yellow R. Aniline diazotised + resorcinol.

Cerotine orange. Aniline diazotised + *m*-toluylenediamine.

Chicago blue B. Dianisidine tetrazotised + 2 mols. S acid.

Chicago blue 2B, 4B, 6B, 2R. Mixed Disazo-dyestuffs with 1 mol. S acid and 1 mol. another compound.

Chicago blue R. Tolidine tetrazotised + 2 mols. S acid.

Chicago orange. *p*-Nitrotoluene sulphonic acid boiled with caustic soda in presence of an amino-compound.

Chloramine green B.

Benzidine tetrazotised $\begin{array}{l} H\ acid,\ diazotised\ +\ dichloroaniline. \\ phenol\ (or\ salicylic\ acid). \end{array}$

Chloramine yellow. Action of alkali hypochlorite on dehydrothio-*p*-toluidine sulphonic acid

Chlorophenine. See *Chloramine yellow.*

Chromacetine blue. Condensation of *Gallocyanines* with aromatic alkylated diamines with free amino-group.

Chromazurine G, E. Isomeric with *Delphine blue.*

Chromazurol S. o-Chlorobenzaldehyde sulphonic acid condensed with salicylic acid; oxidation with nitrosyl sulphate.

Chrome blue. Condensation of tetramethyldiaminobenzhydrol and α-hydroxynaphthoic acid; oxidation.

$$HO.C \diagup \begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4.N(CH_3)_2 \\ C_{10}H_5(OH).COOH \end{matrix}$$
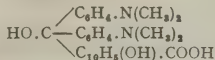
Chrome brown RR. p-Aminophenol disulphonic acid diazotised + pyrogallol.

Chrome green. Benzoic acid condensed with tetramethyldiaminobenzhydrol; oxidation.

$$HO.C \diagup \begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4.N(CH_3)_2 \\ C_6H_4.COOH \end{matrix}$$
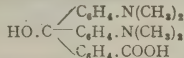
Chrome violet. Tetramethyldiaminobenzhydrol condensed with salicylic acid sulphonated and oxidised.

$$HO.C \diagup \begin{matrix} C_6H_4(OH).COOH \\ C_6H_3(SO_3H).N(CH_3)_2 \\ C_6H_3(SO_3H).N(CH_3)_2 \end{matrix}$$
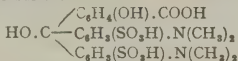
Chrome violet. Formaldehyde and salicylic acid.

$$C \diagup \begin{matrix} C_6H_3(OH).COONa \\ C_6H_3(OH).COONa \\ C_6H_3(COONa) = O \end{matrix}$$
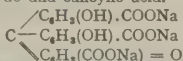
Chrome yellow D. Brönner's acid (or isomer) diazotised + salicylic acid.

Chromogene. Mono sodium salt of dihydroxynaphthalene disulphonic acid **K** oxidised on fibre by dichromate.

Chromotrope 2B. p-Nitraniline diazotised + chromotrope acid.

Chromotrope 6B. p-Aminoacetanilide diazotised + chromotrope acid.

Chromotrope 8B. Naphthionic acid diazotised + chromotrope acid.

Chromotrope 10B. α-Naphthylamine diazotised + chromotrope acid.

Chromotrope 2R. Aniline diazotised + chromotrope acid.

Chromoxan colours. Aldehydes of naphthalene series condensed with hydroxy-acids of benzene series by H_2SO_4; oxidation with nitrosyl sulphate.

Chrysamine G. Benzidine tetrazotised + 2 mols. salicylic acid.

Chrysamine R. Tolidine tetrazotised + 2 mols. salicylic acid.

Chrysaniline. Asymmetrical isomeride of *Benzoflavine* and lower homologue Base of *Phosphine.*

Chrysoidine. Aniline diazotised + m-phenylenediamine.

$$C_6H_5.N : N.C_6H_3 \diagup \begin{matrix} NH_2 \\ NH_2.HCl \end{matrix}$$
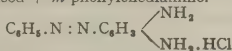
Chrysoine. See *Resorcin yellow.*

Chrysoline. Resorcinol, benzyl chloride, and phthalic anhydride.

Chrysophenine. Diethylated *Brilliant yellow.*

Ciba blue B. Tribromo-indigotine.

Ciba blue 2B. Tetrabromo-indigotine.

Ciba bordeaux B. 5 : 5'-Dibromo-thioindigo.

Ciba heliotrope. Bromination of *Indirubine* in presence of nitrobenzene.

Ciba red B. 6 : 6'-Dichloro-thioindigo.

Ciba scarlet G. Condensation of acenaphthene quinone with oxythionaphthe

$$C_6H_4 \diagup \begin{matrix} S \\ CO \end{matrix} \diagdown C = C \diagdown \begin{matrix} CO \\ \end{matrix}$$
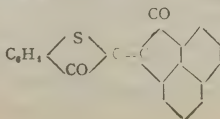
Ciba yellow G. Brominated *Indigo yellow 3G Ciba*.
Cibanone black B, 2B. 2-Methylbenzanthrone fused with sulphur.
Cibanone blue 3G. As *Cibanone black*.
Cibanone brown. Amino-2-methylanthraquinone fused with sulphur.
Cibanone green B. As *Cibanone black*.
Cibanone orange R. From dichloro-methylanthraquinone.
Cibanone yellow R. From ω-monochloro-methylanthraquinone.
Citronin A. Naphthol yellow S.
Citronin. Nitrated *Diphenylamine orange*.
Clayton Fast black D. Action of free thiosulphuric acid on nitrosophenol.
Clayton Cloth red. Dehydrothiotoluidine sulphonic acid diazotised + β-naphthol
Clayton yellow. See *Thiazol yellow G*.
Cloth red B. Amidoazotoluene diazotised + R acid.
Cloth red B extra G. Amidoazobenzene diazotised + N.W. acid.
Cloth scarlet G. Amidoazobenzene monosulphonic acid diazotised + β naphthol.
Coccin 2B. See *Crocein 3BX*.
Cochineal red A. Naphthionic acid diazotised + G acid.
Cochineal scarlet PS. *m*-Xylidine diazotised + R acid (or G acid).
Cochineal scarlet 2R. Toluidine diazotised + α-naphthol sulphonic acid C.
Cochineal scarlet 4R. *m*-Xylidine diazotised + α-naphthol sulphonic acid C.
Cœrulein. Gallein heated with concentrated H_2SO_4.
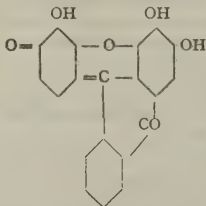
Cœrulein S. Bisulphite compound of Cœrulein.

Columbia black B.

Dianisidine $\Big\langle$ 2 R acid, diazotised + *m*-toluylenediamine.
$\qquad\qquad$ *m*-toluylenediamine.

Columbia black R.

Tolidine $\Big\langle$ 2 R acid, diazotised + *m*-toluylenediamine.
$\qquad\qquad$ *m*-toluylenediamine.

Columbia blue G.

Tolidine tetrazotised $\Big\langle$ S acid.
$\qquad\qquad\qquad$ another compound.

Columbia blue R.

Benzidine $\Big\langle$ S acid.
$\qquad\qquad$ naphthol sulphonic acid.

Congo blue 3B.

Tolidine tetrazotised $\Big\langle$ H acid.
$\qquad\qquad\qquad$ H acid (alkaline soln.).

Congo blue BX. See *Diamine blue BX*.
Congo blue 2BX. See *Diamine blue 2B*.
Congo Corinth B.

Tolidine tetrazotised $\Big\langle$ naphthionic acid.
$\qquad\qquad\qquad$ N.W. acid.

Congo Corinth G.

Benzidine tetrazotised $\Big\langle$ naphthionic acid.
$\qquad\qquad\qquad$ N.W. acid.

Congo Fast blue B.

Dianisidine tetrazotised $\left\langle\begin{array}{l}\alpha\text{-naphthylamine, diazotised} + \epsilon\text{-acid.}\\ \epsilon\text{-acid.}\end{array}\right.$

Congo Pure blue. See *Diamine Pure blue.*
Congo red. Benzidine tetrazotised + 2 mols. naphthionic acid ; sodium salt.
Congo red 4R.

Tolidine tetrazotised $\left\langle\begin{array}{l}\text{naphthionic acid.}\\ \text{resorcinol.}\end{array}\right.$

Congo Rubine.

Benzidine tetrazotised $\left\langle\begin{array}{l}\beta\text{-naphthol-}\alpha\text{-monosulphonic acid.}\\ \text{naphthionic acid.}\end{array}\right.$

Corallin. See *Red* and *Yellow corallin.*
Cotton blue. See *Soluble blue.*
Cotton blue R. See *New blue R.*
Cotton orange G. Primuline diazotised + *m*-phenylenediamine disulphonic acid.
Cotton ponceau. Diaminodixylylphenylmethane tetrazotised + 2 mols. R acid.
Cotton yellow G. Urea by $COCl_2$ on *p*-aminoacetanilide diazotised + salicylic acid.
Cotton yellow R. Primuline diazotised + salicylic acid.
Cresotine yellow G. Benzidine tetrazotised + 2 mols. *o*-cresotinic acid.
Cresotine yellow R. Tolidine tetrazotised + 2 mols. *o*-cresotinic acid.
Crocein B. Aniline diazotised + aniline, diazotised + Schöllkopf's acid.
Crocein 3 BX. Naphthionic acid diazotised + crocein acid.
Crocein orange. See *Brilliant orange G.*
Crocein scarlet 3B. Sulphanilic acid diazotised + aniline, diazotised + crocein acid.
Crocein scarlet 4 BX. See *Cochineal red A.*
Crocein scarlet 7B. Amidoazotoluene sulphonic acid diazotised + crocein acid.
Crystal ponceau or scarlet. α-Naphthylamine diazotised + G acid.
Crystal violet. Hexamethyldiaminofuchsonimonium chloride.

$$C\left\langle\begin{array}{l}C_6H_4.N(CH_3)_2\\ C_6H_4.N(CH_3)_2\\ C_6H_4=N(CH_3)_2.Cl\end{array}\right.$$
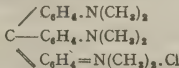
Curcumin S. Action of concentrated alkali on *p*-nitrotoluene sulphonic acid.
$$\begin{array}{l}CH.C_6H_3(SO_3Na).N=\!\!=N.C_6H_3(SO_3Na).CH\\ \|\qquad\qquad\qquad\qquad\qquad\qquad\qquad\|\\ CH.C_6H_3(SO_3Na).N=\!\!=N.C_6H_3(SO_3Na).CH\\ \qquad\qquad\qquad\quad\searrow O\swarrow\end{array}$$
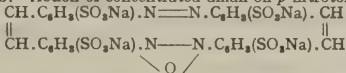
Curcuphenin. See *Chicago orange.*
Cyanamines. Action of primary or secondary amines on Meldola's blue.
Cyanine. See *Quinoline blue.*
Cyanol. *m*-Hydroxybenzaldehyde condensed with 2 mols. monoethyl-*o*-toluidine ; sulphonated, and oxidised.
$$\begin{array}{l}C_6H_2(OH)(SO_3Na)_2\\ \qquad\qquad\qquad\searrow C\left\langle\begin{array}{l}C_6H_3(CH_3).NH(C_2H_5)\\ C_6H_3(CH_3).NH(C_2H_5)\end{array}\right.\\ HO\nearrow\end{array}$$
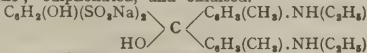
Cyanosine (spirit-soluble). Methyl ester of *Phloxine.*
Cyanthrene. See *Indanthrene dark blue BO.*
Dahlia. See *Hessian purple.*
Dark green. See *Alsace green.*
Dehydroindigo.
$$C_6H_4\left\langle\begin{array}{l}CO\\ N\end{array}\right\rangle C\!-\!C\left\langle\begin{array}{l}CO\\ N\end{array}\right\rangle C_6H$$
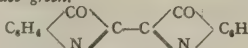
Dehydrothiotoluidine. *p*-Aminophenyltoluthiazol.
$$CH_3\begin{array}{c}\\ \diagdown\diagup S\diagdown\\ C\\ \diagup\diagdown N\diagup\end{array}\diagdown NH_2$$
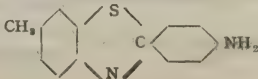
Delphine blue B. *Gallocyanine* heated with aniline, sulphonated.

$$NH.C_6H_4.SO_2NH_4$$

(structure with $-N=$, $-O=$, $(CH_3)_2N$, OH, O)
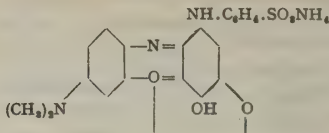
Deltapurpurine.

Benzidine tetrazotised $\Big\langle$ β naphthylamine sulphonic acid F.

Brönner's acid.

Deltapurpurine 7B. Tolidine tetrazotised + 2 mols. β-naphthylamine sulphonic acid F.

Diamine black BH.

Benzidine tetrazotised $\Big\langle$ γ-acid (alkaline soln.).

H acid (alkaline soln.).

Diamine black 3O. Ethoxybenzidine tetrazotised + 2 mols. γ-acid (alkaline soln.).

Diamine black RO. Benzidine tetrazotised + 2 mols. γ-acid (alkaline soln.).

Diamine blue B.

Ethoxybenzidine tetrazotised $\Big\langle$ δ-acid.

N.W. acid.

Diamine blue 2B.

Benzidine tetrazotised $\Big\langle$ H acid.

H acid (alkaline soln.).

Diamine blue 3B.

Tolidine tetrazotised $\Big\langle$ H acid.

H acid (alkaline soln.).

Diamine blue BX.

Tolidine tetrazotised $\Big\langle$ NW acid.

H acid (alkaline soln.).

Diamine blue 3R. Ethoxybenzidine tetrazotised + 2 mols. N.W. acid.

Diamine blue-black.

Ethoxybenzidine tetrazotised $\Big\langle$ δ-acid.

γ-acid (alkaline soln.).

Diamine bronze G.

Benzidine tetrazotised $\Big\langle$ salicylic acid.

H acid (alkaline soln.), diazotised + *m*-phenylene diamine.

(structure)

$$C_6H_4.N:N \quad OH \quad COOH$$
$$OH \quad N:N. \quad NH_2$$
$$C_6H_4.N:N \quad NH_2$$
$$SO_3H \quad SO_3H$$
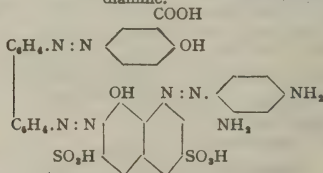
Diamine brown M.

Benzidine tetrazotised $\Big\langle$ salicylic acid.

γ-acid (alkaline soln.).

Diamine brown V.

Benzidine tetrazotised $\Big\langle$ γ-acid (alkaline soln.).

m-phenylenediamine.

Diamine Fast red.

Benzidine tetrazotised $\Big\langle$ salicylic acid.

γ-acid (acid soln.).

Diamine golden-yellow. 1 : 5-Diaminonaphthalene-3 : 7-disulphonic acid tetrazotised + 2 mols. phenol ; ethylated.

Diamine green B.

Benzidine tetrazotised $\Big\langle$ salicylic acid.

H acid (alkaline soln.)

+ diazo-*p*-nitrobenzene (acid soln.).

$$
\begin{array}{c}
\text{COOH} \\
C_6H_4.N:N \bigotimes OH \\
\\
\text{OH NH}_2 \\
C_6H_4.N:N \bigotimes\bigotimes N:N.C_6H_4.NO \\
SO_3H \qquad\qquad SO_3H
\end{array}
$$

Diamine red B.

Tolidine tetrazotised $\Big\langle$ β-naphthylamine sulphonic acid F.

Brönner acid.

Diamine red 3B. Tolidine tetrazotised + 2 mols. β-naphthylamine sulphonic acid F.

Diamine scarlet.

Benzidine tetrazotised $\Big\langle$ G acid ; ethylated.

phenol.

Diamine Sky blue. Dianisidine tetrazotised + 2 mols. H acid.

Diamine violet N. Benzidine tetrazotised + 2 mols. γ-acid (acid solution).

Diamine yellow N.

Ethoxybenzidine tetrazotised $\Big\langle$ salicylic acid ; ethylated.

phenol.

Diaminogen black. 4-Acetamino-α-naphthylamine-6-sulphonic acid diazotised + α-naphthylamine, diazotised + γ-acid ; acetyl group saponified.

Diaminogen blue G. From R acid.

$$
\begin{array}{c}
\text{OH SO}_3H \\
NH_2 \bigotimes N:N \bigotimes N:N \bigotimes \\
SO_3H \qquad\qquad\qquad\qquad SO_3H
\end{array}
$$

Diamond black. Aminosalicylic acid diazotised + α-naphthylamine, diazotised + N.W. acid.

Diamond black PV. o-Aminophenol-*p*-sulphonic acid diazotised + 1 : 5 dihydroxynaphthalene.

Diamond Flavine G. Benzidine tetrazotised + 1 mol. salicylic acid, boiled.

$$
HO.C_6H_4.C_6H_4.N:N \bigotimes \begin{array}{c} OH \\ \\ COOH \end{array}
$$

Diamond green. Aminosalicylic acid diazotised + α-naphthylamine, diazotised + 1 : 8-dihydroxy-naphthalene-4-sulphonic acid.

Diamond green. See *Malachite green.*

Diamond Magenta. Large crystals of *Magenta.*

Diamond yellow G. *m*-Aminobenzoic acid diazotised + salicylic acid.

Dianil black R.

Naphthionic acid diazotised $\Big\rangle$ dihydroxynaphthalene disulphonic acid.

Benzidine tetrazotised $\Big/$

m-phenylenediamine.

Dianil blue B. **Tolidine** tetrazotised + 2 mols. chromotrope acid.

Dianil blue G. Dianisidine tetrazotised + 2 mols. chromotrope acid.

Dianisidine blue. Dianisidine tetrazotised + 2 mols. β-naphthol: copper salt on the fibre.

Dianthine. Di-iodo-fluorescein.

Dianthine. See *St. Denis red.*

Diazo Brilliant scarlets. Thiazol derivatives of J acid coupled with diazobenzene, &c.

Dimethylaniline orange. See *Orange III.*

Dioxine. Action of HNO_2 on 2 : 7-dihydroxynaphthalene. 7-Hydroxy-β-naphthoquinone monoxime.

Diph nylamine blue. Triphenylpararosaniline hydrochloride.

Diphenylamine orange. Sulphanilic acid diazotised + diphenylamine.

Diphenyl Fast yellow. Dinitrodibenzyl disulphonic acid condensed with *Primuline.*

Direct brown J. 2 Mols. *m*-aminobenzoic acid diazotised + 1 mol. *Bismarck brown.*

Direct Sky blue. See *Diamine Sky blue.*

Direct yellow G. *p*-Nitrotoluene sulphonic acid treated with conc. NaOH.

Direct yellow RT. See *Curcumine S.*

Döbner's violet. Amidofuchsonimonium chloride.

$$\begin{array}{c} C_6H_5 \\ NH_2.C_6H_4 \end{array} \bigg\rangle C : C_6H_4 : NH_2Cl$$
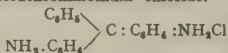
Double Brilliant scarlet G. Brönner acid diazotised + β-naphthol.

Double scarlet S. See *Brilliant ponceau 4R.*

Eclipse browns. Mixtures of *m*-toluylenediamine with several bases and acids, such as oxal-*m*-toluylenediamine, nitrotoluidines, phthalic acid, thiodiglycollic acid, &c., heated with polysulphide.

Eclipse yellow brown B. *m*-Toluylenediamine and oxalic acid heated with polysulphide.

Eclipse red. Sulphurisation of Azines.

Eclipse yellow G, 3G. Fusion of mono- or di-formyl-*m*-toluylenediamine (alone or mixed with benzidine) with sulphur at 240° C.

Eosin A (yellow). Tetrabromo-fluorescein ; sodium salt.

Eosin (bluish). See *Erythrosin.*

Eosin BN. Dibromodinitro-fluorescein ; alkali salt.

Eosin 10B. Tetrachlorotetrabromo-fluorescein.

Eosin S. Ethyl ester of *Eosin.*

Eosin scarlet. See *Eosin BN.*

Erica B. Dehydrothio-*m*-xylidine diazotised + ε-acid.

Eriochlorine. Allied to *Erioglaucine.*

Eriochrome blue-black. B, R. 1-Amino-2-naphthol-4-sulphonic acid diazotised + α or β naphthol.

Eriochrome red B. 1-Amino-2-naphthol-4-sulphonic acid diazotised + 1-phenyl-3-methyl-5-pyrazolone.

$$\begin{array}{c} CH-N : N \\ CH_3.C \ CO \qquad HO \\ \| \\ N-N.C_6H_5 \\ SO_3Na \end{array}$$
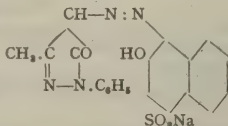
Erio Ch. ime Azurole B. *o*-Chlorobenzaldehyde and *o*-cresotinic acid condensed by H_2SO_4 ; oxidised with nitrosyl sulphate.

Erio Chrome Cyanine. Benzaldehyde-*o*-sulphonic acid and *o*-cresotinic acid condensed by H_2SO_4; oxidised with nitrosyl sulphate.
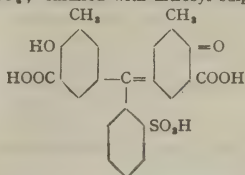
Eriocyanine. Tetramethyldiaminobenzhydrol condensed with dibenzylaniline sulphonic acid; oxidation. Sodium salt.

Erioglaucine A. Benzaldehyde *o*-sulphonic acid condensed with ethylbenzylaniline sulphonic acid; oxidation. Ammonium salt.

Erythrines. Esters of *Eosin*.

Erythrosin B. Tetraiodo-fluorescein.

Ethyl green. See *Brilliant green*.

Ethyl violet. Hexaethylpararosaniline hydrochloride.

Fast Acid violet B. Fluorescein chloride and aniline condensed; sulphonated. Diphenyl-*m*-aminophenolphthalein sulphonic acid.

$$C_6H_4.C \underset{COOH}{\overset{\displaystyle C_6H_3.NH.C_6H_4.SO_3H}{\Big\langle}} \!\!\! {}^{\displaystyle O}_{\displaystyle C_6H_3=N.C_6H_5}$$
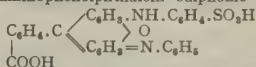
Fast Benzo orange S. Derivative of complex urea obtained by treating J acid with phosgene gas.

Fast black B. 1 : 8-Dinitronaphthalene treated with sodium sulphide in aqueous soln.

Fast blue. See *New blue R*.

Fast blue B. (spirit-soluble). Induline obtained by heating amidoazobenzene with aniline and aniline hydrochloride.

Fast blue B. Sulphonic acid of above.

Fast blue R (spirit-soluble). Induline obtained by heating nitrophenol with aniline and aniline hydrochloride.

Fast blue R. Sulphonic acid of above.

Fast brown. 2 Mols. naphthionic acid diazotised + 1 mol. resorcinol.

Fast browns. Monoazo- and Disazo-dyestuffs from *a*- or *β*-naphthylamine sulphonic acids + *a*-naphthol.

Fast green. See *Alsace green*.

Fast green extra. Tetramethyldibenzyl-pararosaniline disulphonic acid.

$$C \underset{C_6H_4:N(CH_3)_2}{\overset{\displaystyle C_6H_4.N(CH_3)_2}{\Big\langle}} C_6H_4.N \overset{\displaystyle CH_2.C_6H_4.SO_3Na}{\underset{\displaystyle CH_2.C_6H_4.SO_2}{\Big\langle}}$$
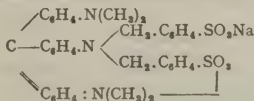
Fast Marine blue. See *New blue R*.

Fast ponceau B. See *Biebrich scarlet*.

Fast red. Naphthionic acid diazotised + Schäffer's acid.

Fast red A. Naphthionic acid (or L acid) diazotised + *β*-naphthol.

Fast red B. *a*-Naphthylamine diazotised + R acid.

Fast red BT. *a*-Naphthylamine diazotised + Schäffer's acid.

Fast red C. Naphthionic acid diazotised + N.W. acid.

Fast red D. Naphthionic acid diazotised + N.W. acid.

Fast scarlet. Aminoazobenzene sulphonic acid diazotised + Schaffer's acid.

Fast yellow G. Aminoazobenzene disulphonic acid; sodium salt.

Fast yellow R. Aminoazotoluene disulphonic acid; sodium salt.

Flavanthrene. Alkaline fusion of β-aminoanthraquinone at a high temperature.
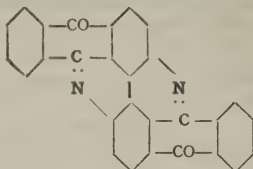
Flavazines. Allied to *Tartrazine.*
Flavopurpurin. 1 : 2 : 6-Trihydroxyanthraquinone.
Fluorescein. Phthalic anhydride condensed with 2 mols. resorcinol.

$$C_6H_4-C\begin{cases}C_6H_3\\C_6H_3\end{cases}\begin{matrix}(OH)\\O\\(OH)\end{matrix}$$
$$CO-O$$
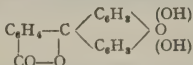
Fluorescent blue. Tetrabromo derivative of Resorufine.
Formyl violet. Formaldehyde condensed with ethylbenzylaniline sulphonic acid ; oxidation ; condensation with diethylaniline ; oxidation.

$$C\begin{cases}\left[C_6H_4.N\begin{cases}C_2H_5\\CH_2.C_6H_4.SO_3Na\end{cases}\right]_2\\C_6H_4:N(C_2H_5)_2.Cl\end{cases}$$
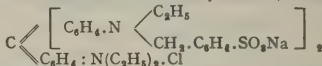
Fuchsia. See *Methylene violet.*
Fuchsine (Fuchsiasine). See *Magenta.*
Gallamine blue. Nitrosodimethylaniline condensed with gallamide.
Gallanil blue. *Gallamine blue* heated with aniline.
Gallein. Phthalic anhydride condensed with pyrogallol. Pyrogallol phthalein or dihydroxy-fluorescein.
Gallocyanine. Nitrosodimethylaniline hydrochloride condensed with gallic acid.
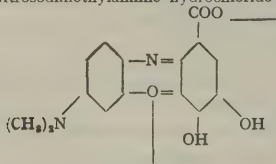
Galloflavine. Oxidation of gallic acid.
Gallo violet. A leuco *Pyrogallocyanine.*
Gambine B. Action of HNO_2 on 2 : 7-dihydroxynaphthalene.
Gambine G, Y. Action of HNO_2 on β-naphthol.
Gentian blue. See *Aniline blue.*
Gold brown. See *Bismarck brown.*
Giroflé. Nitrosodimethylaniline condensed with xylidine.
Glacier blue. Substituted *Malachite green.*
Grenadine. Impure *Magenta.*
Grenat soluble. Isopurpuric acid ; ammonium salt.
Grey B, R. Induline sulphonic acids.
Guinea green B. Benzaldehyde condensed with ethylbenzylaniline sulphonic acid · oxidation.

$$\begin{matrix}C_6H_5\\HO\end{matrix}C\begin{cases}C_6H_4.N(C_2H_5).CH_2.C_6H_4(SO_3Na\\C_6H_4.N(C_2H_5).CH_2.C_6H_4(SO_3Na\end{cases}$$
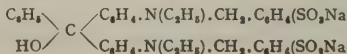
Helianthine. Sulphanilic acid diazotised + dimethylaniline.
Helindone blue 2B. Mainly 5 : 5'-dibromo-indigotine.
Helindone Fast scarlet R. 5 : 5'-Dichloro-6 : 6'-diethoxy-thioindigo.
Helindone grey 2B. 7 : 7'-Diamino-thioindigo.
Helindone grey BR. Dichloro-7 : 7'-diamino-thioindigo.
Helindone orange D. Dibromo-6 : 6'-diamino-thioindigo.
Helindone orange R. 6 : 6'-Diethoxy-thioindigo.
Helindone pink BN. 6 : 6'-Dibromo-dimethyl-thioindigo.
Helindone red B. 5 : 5'-Dimethyl-thioindigo.
Helindone red 3B. 5 : 5'-Dichloro-6 : 6'-dimethyl-thioindigo.
Helindone scarlet S. 6 : 6'-Dithioethyl-thioindigo.
Helindone violet 2B. Dichloro-dimethoxy-thioindigo.
Helindone violet D. Methylindoxyl condensed with isatin ; bromination.
Helindone yellow 3GN. Urea derivative of 2 mols. β-aminoanthraquinone.
Helio Fast red RL. m-Nitro-p-toluidine diazotised + β-naphthol.
Heliotrope B. Dianisidine tetrazotised + 2 mols. ethyl β-naphthylamine sulphonic acid F.
Heliotrope 2B. Benzidine tetrazotised $\Big\langle$ crocein acid.
Schöllkopf's acid.
Helvetia blue. Condensation of formaldehyde with 2 mols. diphenylamine sulphonic acid ; oxidation in presence of 1 mol. diphenylamine sulphoinic acid. Trisulphonic acid of triphenylpararosaniline.
Hessian purple N. Diaminostilbene disulphonic acid tetrazotised + 2 mols. β-naphthylamine.
Hessian yellow. Diaminostilbene disulphonic acid tetrazotised + salicylic acid ; sodium salt.
Hofmann's violet. Mixture of triethyl-pararosaniline and -rosaniline.
Hydrazine yellows. Allied to *Tartrazine.*
Hydron blue B, G, R. Sulphurisation of indophenol-carbazol or derivatives.
Hydron blue-black. Sulphurisation of condensation product of chlorodinitrobenzene with leuco-indophenol-carbazol.
Hydron olive G. Sulphur chloride on anthracene (?)
Hydron yellow G. Dehydration product of diphthaloyl-carbazol.
Immedial black. 1-Chloro-2 : 4-dinitrobenzene and p-aminophenol fused with sodium polysulphide.
Immedial black N. Sulphurisation of dinitrophenol.
Immedial black V extra. Sulphurisation of p-Hydroxy-o'-p'-dinitrodiphenylamine.
Immedial blue. Oxidation of *Immedial black* by H_2O_2.
Immedial blue C. Oxidation of *Immedial black V extra* with H_2O_2. Hydroxydinitrodiphenylamine treated with polysulphide at a low temperature.
Immedial bordeaux. Azines fused with sodium polysulphide.
Immedial bronze. Dinitrocresol fused with polysulphide.
Immedial brown. Hydroxydinitrodiphenylamine treated with NaOH ; fused with sodium polysulphide.
Immedial Indone. From Indophenol obtained by condensing o-toluidine and p-aminophenol.
Immedial maroon. As *Immedial bordeaux.*
Immedial orange C, N. m-Toluylenediamine fused with sulphur at 250°C.
Immedial Pure blue. p-Dimethylaminohydroxydiphenylamine treated with sulphur.
Immedial yellow D. m-Toluylenediamine fused with sulphur at 190°C.
Immedial yellow 2G. From dehydrothiotoluidine and benzidine.
Imperial scarlet. See *Biebrich scarlet.*
Imperial violet. Mixtures of mono- and di-phenyl and tolyl derivatives of pararosaniline and rosaniline.
Indamines. Action of p-nitrosodimethylaniline hydrochloride on hydrochlorides of aromatic amines.

Derivatives of : $N \Big\langle \begin{array}{l} C_6H_4.NH_2 \\ C_6H_4 : NH \end{array}$
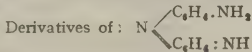
Indanthrene X. Fusion of β-aminoanthraquinone with KOH.

Indanthrene S. By reduction of above by warm soln. of hydrosulphite.
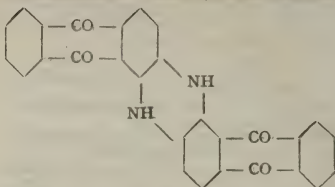
Indanthrene black. *Indanthrene green* chlorinated on the fibre.
Indanthrene blue GC. Dibromo-indanthrene.
Indanthrene blue GCD. Dichloro-indanthrene.
Indanthrene blue 3G, 2GS. Hydroxy-indanthrenes (?)
Indanthrene blue RC. Monobromo-indanthrene.
Indanthrene blue RS. See *Indanthrene X.*
Indanthrene bordeaux B. Allied to *Indanthrene red G.*
Indanthrene dark blue BO. Benzanthrone fused with alkali.
Indanthrene golden orange G. Pyranthrone by dehydration of dimethyl dianthraquinonyl.
Indanthrene golden orange R. Halogenation of above.
Indanthrene green. Nitro-derivative of *Indanthrene dark blue BO.*
Indanthrene grey B. Alkaline fusion of 1 : 5-diaminoanthraquinone.
Indanthrene maroon. Alkaline fusion of formaldehyde compound of 1 : 5 diaminoanthraquinone.
Indanthrene olive G. Anthracene fused with sulphur at 250°C.
Indanthrene red G. 1 Mol. 2 : 6-dichloroanthraquinone condensed with 2 mols α-aminoanthraquinone.
Indanthrene scarlet G. Halogenation of *Indanthrene golden orange G.*
Indanthrene violet RT. Halogenation of *Indanthrene dark blue O.*
Indanthrene yellow. See *Flavanthrene.*
Indazine. Induline from nitrosodimethylaniline and diphenyl-*m*-phenylene-diamine.
Indazurine. Substantive dyestuff for cotton from *p*-diamines and nigrotic acid.
Indian yellow. *Diphenylamine orange* treated with dilute HNO_3.
Indigo, Indigotine.

$$C_6H_4 \diagdown \genfrac{}{}{0pt}{}{NH}{CO} \diagup C:C \diagdown \genfrac{}{}{0pt}{}{NH}{CO} \diagup C_6H$$
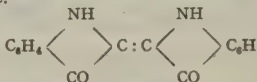
Indigo Pure B.A.S.F. 20 per cent. paste.
Indigo carmine. Indigo disulphonic acid · sodium salt.
Indigo extract. Indigo disulphonic acid.
Indigo salt. *o*-Nitrobenzaldehyde condensed with acetone; bisulphite compound.
Indigotine P. Indigo tetrasulphonic acid; sodium salt.
Indigo white.

$$C_6H_4 \diagdown \genfrac{}{}{0pt}{}{C(OH)}{NH} \diagup C-C \diagdown \genfrac{}{}{0pt}{}{(OH)C}{NH} \diagup C_6H_4$$

or

$$C_6H_4 \diagdown \genfrac{}{}{0pt}{}{CO}{NH} \diagup CH.CH \diagdown \genfrac{}{}{0pt}{}{CO}{NH} \diagup C_6H_4$$
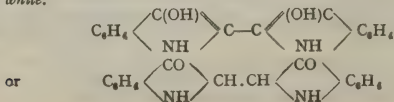
Indigo yellow 3G Ciba. Probably

$$C_6H_4 \diagdown \begin{matrix} CO \\ N \end{matrix} \diagup C : C \diagdown \begin{matrix} CO \\ N \end{matrix} \diagup C_6H_4$$
$$\begin{matrix} | \\ C \\ /\ \backslash \\ H \quad C_6H_5 \end{matrix}$$

Indirubins. Isomer of *Indigotine*.

$$NH \diagdown \begin{matrix} CO \\ C_6H_4 \end{matrix} \diagup C : C \diagdown \begin{matrix} CO \\ NH \end{matrix} \diagup C_6H_4$$
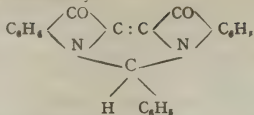
Indocarbon S. Indophenol-carbazol fused with sodium polysulphide in presence of copper sulphate.

Indoine blue R. *Safranine* diazotised + β-naphthol.

Indophenine extra. See *Induline*.

Indophenol. Oxidation of mixture of α-naphthol and dimethyl-*p* phenylene-diamine.

$$(CH_3)_2N.C_6H_4.N = \langle\ \rangle = O$$
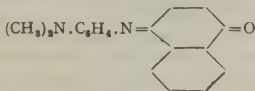
Indophenosafranine. Symmetrical *Safranines*.

Indulines. Phenylamino Mauvines.

Induline 3B. Amidoazobenzene heated with aniline and aniline hydrochloride at 130°C.

Induline 6B. Above heated at 170°C.

Ingrain colours. *Primuline* diazotised + β-naphthol, &c., on the fibre.

Iodine violet. See *Hofmann's violet*.

Irisamine. Ethyl ester of dimethyl-rhodamine.

$$C_2H_5OOC.C_6H_4.C \diagdown \begin{matrix} C_6H_3(CH_3).NH_2 \\ \\ C_6H_3 : N(CH_3)_2.Cl \end{matrix} \diagup O$$
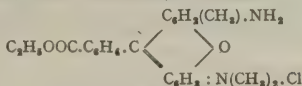
Isamine blue. See *Soluble blue XG*.

Isopurpurin. See *Anthrapurpurin*.

Isorubine. See *New Magenta*.

Janus blue. See *Indoine blue R*.

Janus colours. Amino ammonium bases $\left(\text{Type : Aryl} \diagdown \begin{matrix} NH_2 \\ (alkyl)_3.Cl \end{matrix} \right)$ diazotised + phenol, &c.

Janus red. *m*-Aminophenyltriphenyl ammonium chloride diazotised + *m*-toluidine, diazotised + β-naphthol.

Cl.(CH₃)₃N.C₆H₄.N : N.C₆H₃(CH₃).N : N.C₁₀H₆.OH
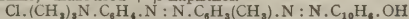
Jasmine. Nitration of *Diphenylamine orange*.

Jet black R. Aminobenzene disulphonic acid diazotised + α-naphthylamine diazotised + phenyl-α-naphthylamine.

Katigen colours. Direct cotton Sulphur dyestuffs.

Katigen black 2B. From chlorodinitrophenol.

Katigen black-brown N. See *Cachou de Laval*.

Katigen red-brown. See *Eclipse red*.

Kryogen blue, G, R. 1 : 8-Dinitronaphthalene reduced with sodium sulphide, sodium bisulphite and NaOH ; intermediate product treated with poly-sulphide.

Kryogen brown. Reduction of 1 : 8-dinitronaphthalene with sulphide or sulphite and subsequent treatment with polysulphide.

Kryogen yellow G. Sulphur dyestuff from thiourea derivatives of *m*-toluylene diamine mixed with benzidine.

Kryogen yellow R. *m*-Toluylenedithiourea fused with sulphur.

Lacmoïd. Action of sodium nitrite on resorcinol.

Lævuline blue. Fast blue (*spirit-soluble*) dissolved in lævulinic acid.

Lake bordeaux B. β-Naphthylamine-α-sulphonic acid diazotised + β-hydroxynaphthoic acid.

Lake red D. Anthranilic acid diazotised + β-naphthol.

Lake red P. *p*-Nitraniline-*o*-sulphonic acid diazotised + β-naphthol.

Lanacyl blue 2B. H acid diazotised + 1 : 4-aminonaphthol.

Lanacyl violet. H acid diazotised + ethyl-α-naphthylamine.

Light blue. See *Aniline blue.*

Light green SF (bluish). Benzaldehyde condensed with methylbenzylaniline sulphonated and oxidised.

Light green SF (yellowish). As above, using ethylbenzylaniline.

$$\text{HO.C} = \left[C_6H_4.N \underset{CH_2.C_6H_4.SO_3Na}{\overset{C_2H_5}{<}} \right]_2$$
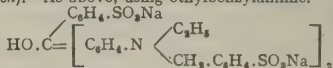
Light Fast yellows. Allied to *Tartrazine.*

Lithol Fast scarlet R. *m*-Nitro-*p*-toluidine diazotised + β-naphthol.

Lithol red R. β-Naphthylamine-α-sulphonic acid + β-naphthol.

Lithol Rubine B. *p*-Toluidine-*o*-sulphonic acid + β-hydroxy-naphthoic acid.

Lyons blue. See *Imperial violet.*

Magdala red. α-Aminoazonaphthalene hydrochloride heated with α-naphthylamine.

Magenta. Pararosaniline hydrochloride and rosaniline hydrochloride.

$$C \underset{C_6H_4=NH_2Cl}{\overset{C_6H_4.NH_2}{<}} \quad C \underset{C_6H_4=NH_2Cl}{\overset{C_6H_3(CH_3).NH_2}{<}}$$
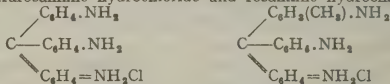
Magenta S. Sulphonated Magenta ; sodium salt.

Malachite green. Benzaldehyde condensed with dimethylaniline by ZnCl₂; oxidation gives tetramethyldiaminotriphenylcarbinol. Zinc chloride double salt, sulphate or oxalate.

$$C_6H_5.C \underset{C_6H_4N(CH_3)_2.Cl}{\overset{C_6H_4.N(CH_3)_2}{<}}$$
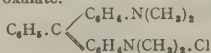
Manchester brown. See *Phenylene brown.*

Manchester yellow. See *Martius yellow.*

Mandarin G extra. See *Orange II.*

Marine blue. See *Diphenylamine blue.*

Maroon. Impure *Magenta* and *Phosphine.*

Martius yellow. 2 : 4-Dinitro-α-naphthol.

Mauveïn. Oxidation of aniline containing toluidine. Phenyltolusafranine chloride, $C_{27}H_{25}N_4Cl$, or $(C_{27}H_{25}N_4)_2SO_4$.

Melanogen blue D. 1 : 5-Dinitronaphthalene treated with polysulphide.

Meldola's blue. Nitrosodimethylaniline hydrochloride and β-naphthol condensed in alcoholic soln. by ZnCl₂.

$$(CH_3)_2.N \underset{=O-}{\overset{=N-}{<}} \quad Cl$$
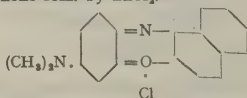
Metanil yellow. Metanilic acid diazotised + diphenylamine.

Methyl Alkali blue. Sulphonic acid of triphenylpararosaniline.

Methyl blue. See *Helvetia blue.*

Methylene azure. Alkaline soln. of *Methylene blue* exposed to air, loss of one methyl group.

Methylene blue. Hydrochloride or zinc chloride double salt,
$$2\ C_{16}H_{18}N_3SCl + ZnCl_2 + H_2O$$

$$(CH_3)_2N.\underset{}{\overset{=N-}{\bigcirc}} \underset{=S-}{\bigcirc}.N(CH_3)_2$$
$$Cl$$
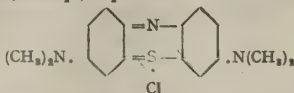
Methylene green. Mononitro Methylene blue by HNO_3 and HNO_2.
Methylene violet. Dimethyl-phenosafranine + $ZnCl_2$.
Methyl green. Methyl chloride on *Methyl violet.*

$$C=\underset{C_6H_4.N(CH_3)_2}{\overset{C_6H_4.N(CH_3)_2}{\bigg\langle}} : N(CH_3)_2.Cl$$
$$C_6H_4.N(CH_3)_2.CH_3Cl$$
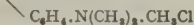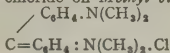
Methyl orange. Sodium or ammonium salt of *Helianthine.*
Methyl violet B, 2B. Pentamethylpararosaniline hydrochloride.

$$C\underset{C_6H_4.N(CH_3)_2.Cl}{\overset{C_6H_4.NH(CH_3)}{\bigg\langle}} : N(CH_3)_2.Cl$$
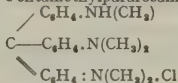
Methyl violet 6B, 7B. See *Benzyl violet.*
Methyl Water blue. See *Helvetia blue.*
Mikado golden yellow. *p*-Nitroluene sulphonic acid oxidised in presence of NaOH. Dinitrostilbene disulphonic acid; sodium salt.
Mikado orange. *p*-Nitrostilbene sulphonic acid treated with NaOH and a reducing agent.
Mikado yellow. See *Stilbene yellow 8G.*
Milling orange. Aminoazobenzene sulphonic acid diazotised + salicylic acid.
Modern blue (1900). Leuco-compound of Gallamine blue.
Modern blue CVI. } Derived from Gallocyanine.
Modern Cyanines. }
Modern heliotrope PH. Nitroso-monoethyl-*o*-toluidine condensed with gallamide; reduced to leuco-compound.
Modern violet. Leuco-compound of a Gallocyanine.
Modern violet N. Leuco-compound of a Pyrogallocyanine.
Mordant yellow O. See *Chrome yellow D.*
Muscarine. Nitrosodimethylaniline hydrochloride condensed with 2 : 7-dihydroxynaphthalene.

$$N\underset{C_6H_3\ N(CH_3)_2.Cl}{\overset{C_{10}H_5.OH}{\bigg\langle}}O$$
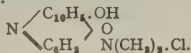
Naphthalene Acid black. Metanilic acid diazotised + Cleve's acids, diazotised + α-naphthylamine.
Naphthazarin S. See *Alizarin black S.*
Naphthindone. See *Indoine blue R.*
Naphthol black B. Amino G salt diazotised + α-naphthylamine, diazotised + R acid.
Naphthol black 6B. α-Naphthylamine disulphonic acid diazotised + α-naphthylamine, diazotised + R acid.
Naphthol blue B, D, R. See *Meldola's blue.*
Naphthol blue-black B, S. *p*-Nitraniline diazotised + H acid (acid soln.), + aniline diazotised (alkaline soln.).
Naphthol green B. HNO_2 on Schäffer's acid.

$$\left[C_{10}H_5\overset{SO_3Na}{\underset{O}{-NO}} \right]_2 Fe$$
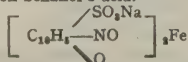
α-Naphthol orange. See *Orange I.*
β-Naphthol orange. See *Orange II.*
Naphthol red. See *Fast red.*
Naphthol yellow S. Nitration of α-naphthol-2 : 4 : 7-trisulphonic acid.

$$SO_3H \underset{NO_2}{\overset{OH}{\bigotimes}} NO_2$$
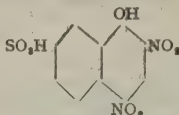
Napthorubin. α-Naphthylamine diazotised + Schöllkopf's acid.
Naphthylamine black D. α-Naphthylamine disulphonic acid diazotised + α-naphthylamine, diazotised + α-naphthylamine.
α-Naphthylamine bordeaux. α-Naphthylamine diazotised + β-naphthol.
Naphthylamine yellow. See *Martius yellow.*
Naphthyl blue. Nitroso-β-naphthylamine heated with aniline hydrochloride.
Naphthyl violet. Nitroso-β-naphthylamine heated with α-naphthylamine hydrochloride.
Naphthylene blue R. See *Meldola's blue.*
Neutral red. Oxidation of mixture of dimethyl-*p*-phenylenediamine and *m*-toluylenediamine ; or soln. of *Toluylene blue* heated.

$$Cl(CH_3)_2N : \bigcirc = N - \bigcirc \overset{CH_3}{\underset{NH_2}{}}$$
$$-NH-$$
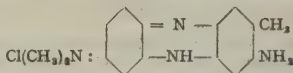
Neutral violet. As above, using *m*-phenylenediamine.
New blue B. *New blue R* condensed with dimethyl-*p*-phenylenediamine.
New blue R. *Meldola's blue* + ZnCl₂.
New Coccine. Naphthionic acid diazotised + G acid.
New Fast Cotton blue. See *New blue R.*
New green. See *Malachite green.*
New Magenta. From *o*-toluidine and formaldehyde. Triaminotritolylcarbino

$$C \overset{C_6H_3(CH_3).NH_2}{\underset{C_6H_3(CH_3) : NH.HCl}{\overset{\displaystyle C_6H_3(CH_3).NH_2}{}}}$$
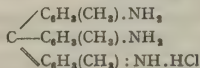
New Methylene blue N. From *p*-amino-monoethyl-*o*-toluidine and ethyltoluidine.
New Methylene blue NGG. Dimethylamine on Meldola's blue.

$$(CH_3)_2N \bigcirc \overset{= N -}{\underset{Cl}{= O -}} N(CH_3)_2$$
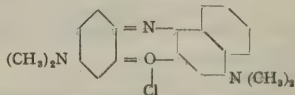
New red L. See *Biebrich scarlet.*
New Victoria blue B. See *Victoria blue R.*
New yellow. See *Diphenylamine orange.*
New yellow. See *Fast yellow G.*
Night blue. Ketone base condensed with *p*-tolyl-α-naphthylamine.

$$C \overset{C_{10}H_6.NH.C_6H_4.CH_3}{\underset{C_6H_4.N(C_2H_5)_2.Cl}{\overset{\displaystyle C_6H_4.N(C_2H_5)_2}{}}}$$
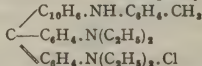
Nigrosine (spirit-soluble). Impure *Induline.* Nitrobenzene, aniline, aniline hydrochloride, and iron heated at about 180°C.
Nigrosine (soluble). Sulphonic acid of above.

Nile blue. Nitrosodimethyl-*m*-aminophenol condensed with α-naphthylamine.
Nile blue A. Nitrosodiethyl-*m*-aminophenol condensed with α-naphthylamine.

$$(C_2H_5)_2N \left\langle \begin{array}{c} =N- \\ =O- \end{array} \right\rangle NH_2$$

C
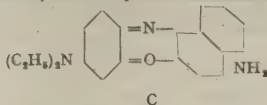
Nile blue 2B. As above, using benzyl-α-naphthylamine.

p-Nitraniline red. *p*-Nitraniline diazotised + β-naphthol on the fibre.

Nitrazole. *p*-Diazonitrobenzene sulphate + NaHSO₃.

Nitrosamine red. *p*-Nitrophenylnitrosamine, sodium salt.

$$C_6H_4 \left\langle \begin{array}{c} NO_2 \\ N:N.ONa \end{array} \right.$$
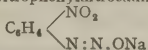
Opal blue. See *Aniline blue.*
Orange I. Sulphanilic acid diazotised + α-naphthol.
Orange II. Sulphanilic acid diazotised + β-naphthol.
Orange III. See *Methyl orange.*
Orange No. 3. *m*-Nitraniline diazotised + R acid.
Orange IV. See *Diphenylamine orange.*
Orange G. Aniline diazotised + G acid.
Orange GRX. See *Brilliant orange G.*
Orange GS. See *Orange IV.*
Orange GT. Toluidine diazotised + Schäffer's acid.
Orange N. See *Orange IV.*
Orange P. See *Orange II.*
Orange R. *o*-Toluidine monosulphonic acid diazotised + β-naphthol.
Orange R extra. See *Orange I.*
Orange RN. See *Orange G.*
Orcelline. Aminoazotoluene monosulphonic acid diazotised + N.W. acid.
Orchil substitute V. *p*-Nitraniline diazotised + naphthionic acid.
Orchil substitute 3VN. *p*-Nitraniline diazotised + L acid.
Orient yellow. See *Dianthine.*
Oriol yellow. See *Cotton yellow R.*
Oxamine blue B. Dianisidine tetrazotised ⟨ J acid. / N.W. acid.
Oxamine blue 3R. Tolidine tetrazotised ⟨ J acid (alkaline soln.) / N.W. acid.
Oxamine red. Benzidine tetrazotised ⟨ J acid. / salicylic acid.
Oxamine violet. Benzidine tetrazotised ⟨ J acid. / J acid (alkaline soln.).
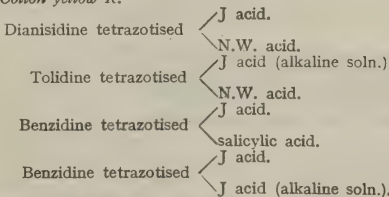
Oxyphenine. Mixture of sulphonic acids of dehydrothiotoluidine and *Primuline* oxidised.

Pæonin. Crude Aurin heated under pressure with ammonia.

Palatine black 4B. S acid + 2 mols. diazotised *p*-toluidine (alkaline soln.), or 1 mol. diazotised sulphanilic acid (acetic acid soln.) + 1 mol. diazotised *p*-toluidine.

Palatine Chrome black 6B. 1-Amino-2-naphthol-4-sulphonic acid diazotised + β-naphthol.

Palatine Chrome blue. 1-Amino-2-naphthol-4-sulphonic acid diazotised + α-naphthol.

Palatine red. α-Naphthylamine diazotised + α-naphthol-3 : 6-disulphonic acid.

Palatine scarlet. *m*-Xylidine diazotised + α-naphthol-3 : 6-disulphonic acid.

Paramine brown. Oxidation of *p*-phenylenediamine on the fibre.

Paramagenta. See *Pararosaniline.*
Para red. See *p-Nitraniline red.*
Pararosaniline. Triaminotriphenylcarbinol, of which the hydrochloride diaminofuchsonimonium chloride.

$$H_2N\langle\rangle-C-\langle\rangle NH_2$$

$$H-N-H$$
$$|$$
$$Cl$$
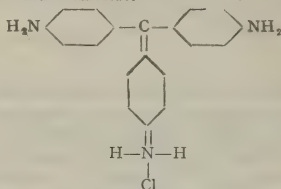
Patent blue. m-Hydroxybenzaldehyde condensed with diethylaniline sulphonated ; converted into calcium salt ; oxidised.

$$(C_2H_5)_2N-C_6H_4-C=C_6H_4=N\langle{}^{C_2H_5}_{C_2H_5}$$

$$-SO_2$$

$$HO$$

$$SO_3\ \frac{Ca}{2}$$
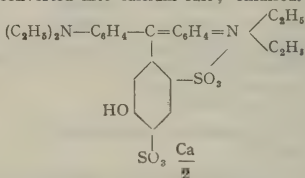
Patent blue A. As above, using ethylbenzylaniline.
Perkin's violet. See *Mauveïn.*
Permanent red 4B. See *Lithol Rubin B.*
Phenolphthalein. Action of phthalic anhydride on phenol in presence of $ZnCl_2$ or H_2SO_4.

$$C_6H_4\cdot C\langle{}^{C_6H_4OH}_{C_6H_4OH}$$
$$|$$
$$CO\cdot O$$
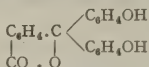
Phenylene black. See *Anthracite black.*
Phenylene blue. Simplest *Indamine.*
Phenylene brown. See *Bismarck brown.*
Phenyl violet. See *Imperial violet.*
Phloxin. Dichlorotetrabromo-fluorescein.

$$C_6H_4Cl_2-C\langle{}^{C_6HBr_2(ONa}_{C_6HBr_2:O}\rangle O$$
$$|$$
$$COOK$$
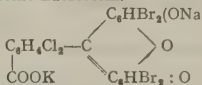
Phosphine. Diaminophenylacridine

$$C_6H_4\langle{}^N_C\rangle C_6H_3.NH_2.C_6H_4.NH_2$$
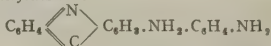
and higher homologue nitrates or hydrochlorides.
Picric acid. 1 : 2 : 4 : 6-Trinitrophenol.
Pigment Fast red HL. See *Helio Fast red RL.*
Pigment orange R. p-Nitro-o-toluidine diazotised + β-naphthol.
Pigment purple. o-Anisidine diazotised + β-naphthol.
Pigment scarlet 3B. Anthranilic acid diazotised + R salt.
Polychromin B. p-Nitrotoluene sulphonic acid and p-phenylenediamine treated with NaOH.

Ponceau B extra. See *Biebrich scarlet.*

Ponceau 2G. Aniline diazotised + R acid.

Ponceau G. Xylidine diazotised + G acid.

Ponceau 4GB. See *Brilliant orange.*

Ponceau R, 2R. Xylidine diazotised + R acid.

Ponceau 3R. 4-Cumidine diazotised + R acid.

Ponceau 5R. Aminoazobenzene diazotised + β-naphthol-3 : 6 : 8-trisulphonic acid.

Ponceau 6R. Naphthionic acid diazotised + β-naphthol-3 : 6 : 8-trisulphonic acid.

Ponceau 3 RB. Aminoazobenzene disulphonic acid diazotised + β-naphthol.

Primuline. 2 Mols. *p*-toluidine heated with 4-5 atoms sulphur at 200—280° ; sulphonation with fuming sulphuric acid. Mixture of compounds of the type :

$$CH_3.C_6H_3\left\langle{S \atop N}\right\rangle C.C_6H_3\left\langle{S \atop N}\right\rangle C.C_6H_3\left\langle{S \atop N}\right\rangle C.C_6H_3\left\langle{SO_3Na \atop NH_2}\right.$$
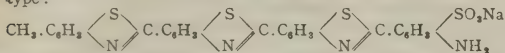
Prune. Nitrosodimethylaniline condensed with methyl ester of gallic acid .
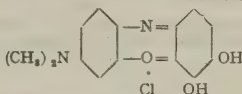
Purpurin. 1 : 2 : 4-Trihydroxyanthraquinone.

Pyramine orange 3G.

Benzidine tetrazotised $\left\langle\begin{array}{l}m\text{-phenylenediamine disulphonic acid.}\\ \text{nitro-}m\text{-phenylenediamine.}\end{array}\right.$

Pyramine orange R. Benzidine disulphonic acid tetrazotised + 2 mols. nitro-*m*-phenylenediamine.

Pyramine orange 2R.

Benzidine tetrazotised $\left\langle\begin{array}{l}\text{amino R acid.}\\ \text{nitro-}m\text{-phenylenediamine.}\end{array}\right.$

Pyranthrone. See *Indanthrene golden orange G.*

Pyrogallocyanines. Loss of CO_2 from COOH group of *Gallocyanines* on heating with water.

Pyrogen blue R.
Pyrogen Direct blue. } Hydroxydinitrodiphenylamine treated with polysulphide
Pyrogen grey G, R. } in alcoholic soln.

Pyrogen green C, FB, 2F, 2G, 3G. *p*-Aminophenol or derivative heated with sodium polysulphide in presence of copper.

Pyrogen indigo. Indophenol from phenylamino-*p*-hydroxydiphenylamine fused with polysulphide.

Pyrogen olive N. } Aromatic methylamino-, nitroamino-, hydroxybenzyl-
Pyrogen yellow M. } amino-, &c., compounds fused with polysulphide.

Pyronine G. Formaldehyde condensed with dimethyl-*m*-aminophenol ; dehydrated ; oxidised.
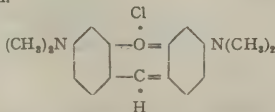
Quinalizarin. See *Alizarin bordeaux.*

Quinizarin. 1 : 4-Dihydroxyanthraquinone.

Quinoline blue. From amyl iodide, quinoline and lepidine ; action of NaOH.

Quinoline yellow. Quinophthalone $C_6H_4.CO : CH.C_9H_6N$, or its sulphonic acids

$$\dot{C}O - \dot{C}$$

Quinoline red. Benzotrichloride on quinaldine and isoquinoline in presence of $ZnCl_2$.

$$C_6H_5.C \begin{cases} CH_2.C_9H_6N \\ C_9H_6 : N.Cl \end{cases}$$
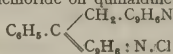
Radial yellows. Allied to *Xylene yellows*.

Red corallin. See *Pæonin*.

Red violet 5R extra. Triethyl magenta.

Resazurin. Oxidation of *Resorufin*.

Resorcin brown.

Xylidine diazotised ⎫
                    ⎬ resorcinol.
Sulphanilic acid diazotised ⎭

Resorcin yellow. Sulphanilic acid diazotised + resorcinol.

$$SO_3Na.C_6H_4.N : N - \langle \ \rangle OH$$
$$OH$$
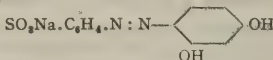
Resorufamin. Quinonedichlorimide condensed with resorcinol.

Resorufin. HNO_3 containing nitrous fumes on ethereal soln. of resorcinol.
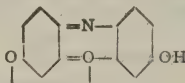
Rheonine. *m*-Amino-phenyl-Auramine chloride heated.

$$(CH_3)_2N.C_6H_4.C \begin{cases} C_6H_3 . N(CH_3)_2 \\ \overline{\qquad} \\ C_6H_3 . NH_2 \end{cases} N$$
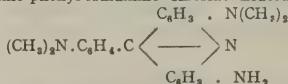
Rhodamine B. Phthalic anhydride condensed with diethyl-*m*-aminophenol.

$$C_6H_4.C \begin{cases} C_6H_3 . N(C_2H_5)_2 \\ O.Cl \\ COOH \quad C_6H_3 . N(C_2H_5)_2 \end{cases}$$
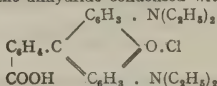
Rhodamine 3B. Ethyl ester of *Rhodamine B*.

$$(C_2H_5)_2N \langle \ \rangle \begin{matrix} Cl \\ =O - \\ =C - \end{matrix} \langle \ \rangle N(C_2H_5)_2$$
$$C_6H_4.COOC_2H_5$$
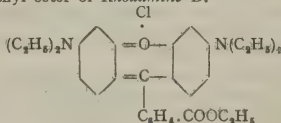
Rhodamine 6G. Monoethyl-*m*-aminophenol phthalein, ethyl ester.

Rhodamine S. Dimethyl-*m*-aminophenol succinein.

$$C_2H_4.C \begin{cases} C_6H_3 . N(C_2H_5)_2 \\ O.Cl \\ COOH \quad C_6H_3 . N(C_2H_5)_2 \end{cases}$$
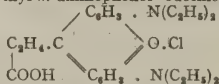
Rhoduline red. Safranine obtained by oxidation of 1 mol. *p*-aminomonoethyl-*o*-toluidine, 1 mol. monoethyl-*o*-toluidine, and 1 mol. aniline.

Roccelline. See *Fast red A*.

Rosamines. Benzotrichloride heated with a dialkyl-*m*-aminophenol.

$$C_6H_5.C \underset{C_6H_3 . NR_2}{\overset{C_6H_3 . NR_2}{<}} O.Cl$$
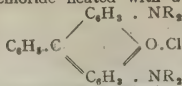
Rosaniline. Triaminodiphenyltolylcarbinol, of which the hydrochloride is diaminomethylfuchsonimonium chloride.
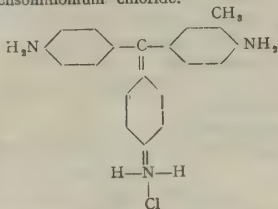
Rosanthrene O. *m*-Nitrobenzoyl chloride condensed with J acid reduced coupled with diazotised aniline
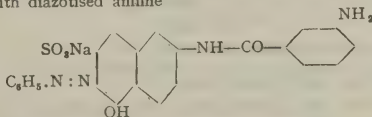
Rosazine. See *Azocarmine.*
Rose Bengal N. Dichlorotetraiodo-fluorescein; potassium salt.
Rose Bengal 3B. Tetrachlorotetraiodo-fluorescein.
Rosindone. Rosinduline heated with HCl, or from *o*-aminodiphenylamine and hydroxynaphthaquinone.

$$C_6H_4 \underset{\dot{C}_6H_5}{\overset{N}{<}} C_{10}H_5=O$$
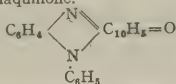
Rosinduline (phenyl). Benzene-azo-α-naphthylamine, aniline, and aniline hydrochloride; or nitrosodimethyl-α-naphthylamine and aniline.

$$C_6H_4 \underset{H_5.\ Cl}{\overset{N}{<}} C_{10}H_5.NH(C_6H_5)$$
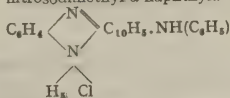
Rosolic acid. Methyl *Aurin.*
Rubine. *Magenta* free from arsenic.
Rufigallol. H_2SO_4 on gallic acid, 1 : 2 : 3 : 5 : 6 : 7-hydroxyanthraquinone.
Russian green. See *Alsace green.*
Safraniline. See *Rhodamine B.*
Safranine T. *o*-Toluidine treated with nitrous fumes; oxidation. Oxidation of *p*-toluylenediamine and *o*-toluidine; condensation of Indamine obtained with *o*-toluidine.

$$NH_2.(CH_3)C_6H_3 \underset{C_6H_5.\ Cl}{\overset{N}{<}} C_6H_3(CH_3).NH_2$$
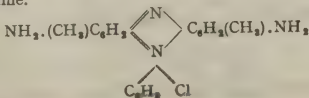
Scarlet EC. See *Biebrich scarlet.*
Scarlet GR. Xylidine diazotised + Schäffer's acid ; sodium salt.
Setocyanine, Setoglaucine. Allied to Erioglaucine.
Soluble blue. Aniline blue di- and tri- sulphonic acids ; ammonium or sodium salts.
Soluble blue XG. β-Naphthylpararosaniline trisulphonic acid.
Soluble Cotton blues. *Aniline blue* tri- and tetra- sulphonic acids.
Soluble Eosines. Sodium and potassium salts of *Eosine.*
Soluble primrose. See *Erythrosine B.*
Soluble Silk blue. *Aniline blue* disulphonic acid.
Soluble Sky blue. See *Helvetia blue.*
Soudan G. Aniline diazotised + resorcinol.
Soudan III. Aminoazobenzene diazotised + β-naphthol.
Spirit blue. See *Aniline blue.*
Spirit Eosines. See *Erythrines.*
Spirit primrose. Fluorescein brominated in alcoholic soln. and heated under pressure.

$$C_6H_4 \Big\langle {{C_6HBr_3-OK \atop C}\atop{C_6HBr_2=O \atop COOC_2H_5}} \Big.$$
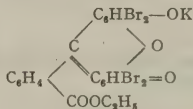
Spirit Sky blue. See *Diphenylamine blue.*
St. Denis red. Diaminoazoxytoluene tetrazotised + 2 mols. N.W. acid.
Stilbene orange 4R. See *Mikado orange.*
Stilbene yellow 8G.

$$\begin{array}{l} CH.C_6H_3(SO_3H).N : N . C_6H_3(SO_3H) . CH \\ \| \qquad\qquad\qquad\qquad\qquad\qquad\qquad \| \\ CH.C_6H_3(SO_3H).NO_2NO_2.C_6H_3(SO_3H).CH \end{array}$$
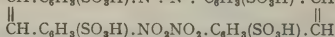
Sulphur black T extra. Dinitrophenol treated with aqueous soln. of polysulphide
Sun yellow. See *Curcumine S.*
Tannin heliotrope. See *Giroflé.*
Tartrazine. Sodium dioxytartrate heated with 2 mols. phenylhydrazine -*p*-sulphonic acid ; or oxalacetic ether heated with phenylhydrazine -*p*-sulphonic acid, diazotised sulphanilic acid added, and saponification.

$$\begin{array}{l} COONa \\ \cdot \\ C : N \\ \cdot \qquad\quad \big\rangle N.C_6H_4.SO_3Na \\ C.CO \\ \cdots \\ N.NH.C_6H_4.SO_3Na \end{array}$$
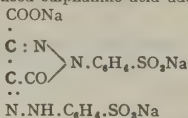
Terracotta F. *m*-Phenylenediamine $\Big\langle {\text{diazotised } Primuline. \atop \text{diazotised naphthionic acid.}}$

Thiazol yellow G. Dehydrothiotoluidine sulphonic acid diazotised + further mol. same.
Thiocarmine R. Diethyldibenzylthionine disulphonic acid.
Thioflavine S. Sulphonated *Primuline.*
Thioflavin T. Dehydrothiotoluidine heated with methyl alcohol and HC under pressure.

$$CH_3.C_6H_3 \Big\langle {S \atop N} \Big\rangle C.C_6H_4.N(CH_3)_2.HCl$$
$$\qquad\qquad CH_3 \quad Cl$$
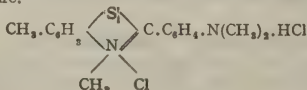
Thiogen dark red G, R. } Azines fused with sodium polysulphide.
Thiogen purple. }

Thioindigo B. From thiosalicylic acid.

$$C_6H_4 \underset{S}{\overset{CO}{\diagdown}} C:C \underset{S}{\overset{CO}{\diagup}} C_6H_4$$
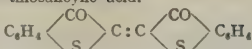
Thioindigo grey B. 7 : 7'-Diamino-thioindigo.
Thioindigo orange R. 6 : 6'-Diethoxy-thioindigo.
Thioindigo pink BN. 6 : 6'-Dibromodimethyl-thioindigo.
Thioindigo red B. See *Thioindigo B.*
Thioindigo red 3B. 5 : 5'-Dichloro-6 : 6'-dimethyl-thioindigo.
Thioindigo red BG. 5 : 5'-Dichloro-thioindigo.
Thioindigo scarlet R. Isatin condensed with hydroxythionaphthen.

$$C_6H_4 \underset{S}{\overset{CO}{\diagdown}} C:C \underset{C_6H_4}{\overset{CO}{\diagup}} NH$$
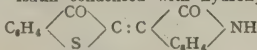
Thioindigo scarlet S. 6 : 6'-Dithioxyl-thioindigo.
Thioindigo violet 2B. Dichlorodimethyldimethoxy-thioindigo.
Thion blue B. p-Nitro-o-amino-p'-hydroxydiphenylamine heated with CS_2 in alcoholic soln.; sulphurised.
Thio Katigen colours. Acetyl-p-phenylenediamine, or other p-diamine, nitro-acetanilide, &c., fused with sodium polysulphide.
Thion brown. Sulphur dyestuff from aniline-azo-m-toluylenediamine.
Thion yellow G. Thio-m-toluylenediamine heated with sodium sulphide soln.
Thional bronze, ⎫ Fusion of β-hydroxynaphthaquinone anilides with
Thional brown G,&c ⎭ sodium polysulphide.
Thiophenol black T extra. Dinitrophenol fused with polysulphides.
Thiophosphine. See *Chloramine yellow.*
Thiophor bronze 5G. Fusion of p-phenylenediamine and p-aminoacetanilide with sulphur.
Thiophor bronze G. As above, with addition of benzidine.
Titan Comos. See *Soluble blue XG.*
Toluidine blue O.

$$N \underset{C_6H_3:N(CH_3)_2.Cl}{\overset{C_6H_2(CH_3).NH_2}{\diagup\diagdown}}$$
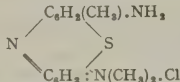
Tolusafranine. See *Safranine T.*
Toluylene blue. Oxidation of dimethyl-p-phenylenediamine and m-toluylene-diamine ; or action of nitrosodimethylaniline hydrochloride on m-toluylene-diamine.

$$Cl.(CH_3)_2N: \underset{NH_2}{\bigcirc} =N— \underset{NH_2}{\bigcirc} \overset{CH_3}{}$$
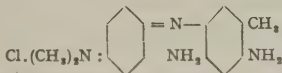
Toluylene brown G. 1 Mol. toluylenediamine sulphonic acid tetrazotised + 1 mol. m-phenylenediamine.

$$SO_3Na.C_6H_3(CH_3) \underset{N:N}{\overset{N:N}{\diagdown}} C_6H_3(NH_2)_2$$
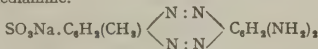
Toluylene brown R.

Naphthionic acid diazotised ⎱ m-phenylenediamine.

Toluylenediamine sulphonic acid tetrazotised ⎰

Naphthionic acid diazotised ⎱ m-phenylenediamine.

Toluylene orange G.

Tolidine tetrazotised ⎡ o-cresotinic acid.
⎣ m-toluylenediamine sulphonic acid.

Toluylene orange R. Tolidine tetrazotised + 2 mols. *m*-toluylenediamine sulphonic acid.

Toluylene red. See *Neutral red.*

Tropæoline G. See *Metanil yellow.*

Tropæoline O. See *Resorcin yellow.*

Tropæoline 20. See *Diphenylamine orange.*

Ultra violet dyestuffs. Quinhydrones by condensation of a leuco-Gallocyanine with a Gallocyanine.

Uranine. Sodium salt of fluorescein.

$$NaO - \bigcirc - O - \bigcirc = O$$
$$C =$$
$$\bigcirc$$
$$COONa$$
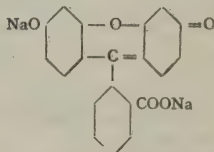
Verde Italiano. Fusion of *p*-aminophenol or its substituted derivatives with polysulphides in presence of copper sulphate at 180°—200°C.

Vesuvine. See *Phenylene brown.*

Vesuvine B. *m*-Toluylenediamine tetrazotised + 2 mols. *m*-toluylenediamine.

Victoria black B. Sulphanilic acid diazotised + α-naphthylamine, diazotised + dihydroxynaphthalene sulphonic acid S.

Victoria blue B. Ketone base condensed with phenyl-α-naphthylamine.

$$C_6H_4.N(CH_3)_2$$
$$C - C_6H_4.N(CH_3)_2$$
$$C_{10}H_6 : NH(C_6H_5).Cl$$
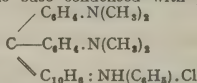
Victoria blue R. As above, using ethyl-α-naphthylamine.

Victoria blue 4R. Methylated *Victoria blue B.*

Victoria violet 4BS. *p*-Aminoacetanilide diazotised + 1 : 8-dihydroxynaphthalene-3 : 6-disulphonic acid ; acetyl group saponified.

Vidal black. Fusion of *p*-aminophenol or a *p*-diamine with polysulphide.

Violamine B. See *Fast Acid violet B.*

Violamine G, R, 2R. Aromatic amines condensed with fluorescein chloride may be sulphonated.

Violanthrone BS. See *Indanthrene violet RT.*

Violet black. *p*-Phenylenediamine tetrazotised $\langle$ α-naphthylamine. / N.W. acid.

Water blue. See *Soluble blue.*

Wool green G. Ketone base condensed with β-naphthol ; sulphonated.

$$C_{10}H_6.OH$$
$$C - C_6H_4.N(CH_3)_2$$
$$C_6H_4.N(CH_3)_2.Cl$$
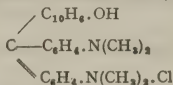
Wool scarlet R. Xylidine diazotised + α-naphthol-4 : 8-disulphonic acid.

Xanthine. See *Phosphine.*

Xylene yellows. Dichloro sulphonic acids of 1-phenyl-3-methyl-5-pyrazolone.

$$CH_3 (4)$$
$$(3) CH_3.C \quad CO (5)$$
$$(2) N - N - C_6H_5 (1$$
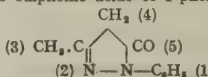
Xylidine orange. See *Brilliant orange R.*

IDENTIFICATION OF DYESTUFFS IN SUBSTANCE AND ON THE FIBRE.

A. In Substance.

Detection of a Mixture.

The majority of the available brands of dyestuffs are mixtures of two or more type-dyestuffs, or of one principal with one or more shading colours present in smaller quantities.

As examples of such mixtures may be mentioned :

(a) Acid dyestuffs : many of the Scarlets and Ponceaux, the Soluble and Alkali blues, the Acid violets, the Patent blue and Erioglaucine brands, several of the important Azo Acid blacks (Höchst).

In some cases dyestuffs are mixed in order to obtain a shade of a fastness which is not otherwise possible, *e.g.*, the Anthracyanines of Bayer, mixtures of Alizarin Saphirole with Azomagenta, Anthracyanine greens, mixtures of Alizarin Saphirole with Fast Light yellow, and the Anthracyanine browns, mixtures of Alizarin Saphirole with Fast Light yellow and Azofuchsine. These mixtures possess the advantage of good fastness to light combined with fairly good level dyeing capacity. In other instances a dyestuff of outstanding fastness to light which does not level very well may be mixed with another colour of similar shade, of somewhat inferior fastness to light, but good levelling capacity, the object being to obtain a mixture possessing both properties in a fair degree. Thus some of the Alizarin Direct blues (Höchst), and Alizarin Cyanol (Cassella) are mixtures of an Alizarin Saphirole colour with Patent blue or Cyanol.

(b) Substantive or salt dyestuffs : many of the Direct blues and blacks are mixtures of several types.

The Union and Duatol colours of Cassella are in many cases mixtures of direct and neutral dyeing acid colours designed to give a solid shade on union materials (wool and cotton), when dyed in a bath with addition of Glauber's salt.

Dyestuffs are frequently mixed in the powdered state, and the following simple tests will serve to detect whether a mixture is present :

1. A small amount of the powder is blown on to the surface of some concentrated sulphuric acid. The colour reactions which most coal-tar dyestuffs yield with concen-

trated sulphuric acid are so characteristic and varied that mixtures are frequently detected in this manner by the totally different colorations given by the particles of the various constituents of the admixture.

2. A further test is to dip small pieces of filter-paper into water, alcohol, dilute sulphuric acid, or dilute caustic soda, allow to drain for a moment, and then blow a minute quantity of the powdered dyestuff on to the various pieces of filter-paper. The particles of the different dyestuffs in a mixture will in the majority of cases give different colour reactions on the sheets of paper wetted with the various liquids given above.

These two tests alone will suffice to decide in most instances whether the sample consists of a single dyestuff or a mixture.

In case a solution is to be investigated, or the solid dyestuff has been produced by mixing the constituents in solution and subsequently evaporating to dryness, the above tests are not suitable, and the method of Goppelsröder is used. Long strips of filter-paper, from one to two inches wide, are suspended with the ends dipping into moderately dilute solutions of the dyestuff under examination, and allowed to stand if necessary for several hours. Different dyestuffs rise up the strips of filter-paper with varying velocities, and a mixture of dyestuffs in solution will often yield on standing a number of differently coloured zones on the strip, corresponding roughly to the various constituents of the mixture. These coloured zones may then be cut out, and further tested by spotting with the reagents used in the tables for the identification of individual dyestuffs referred to later. To confirm any indications of the presence of a mixture obtained by the above capillary test, and having ascertained the dyeing group or groups of the different colouring matters present as described later, small skeins of woollen, cotton, or tanned cotton yarn (as the case may require), are carefully dyed for a short time in the warm to boiling dyestuff-solution with the necessary additions of dilute acid or Glauber's salt, according to the class of dyestuff, acid, substantive, etc., previously found to be present. Each skein is dyed only for a short time, and is replaced by other skeins of material as the temperature rises, further additions of acid or Glauber's salt being made to gradually exhaust the bath. In this manner a fractional dyeing of the different skeins is effected, thus enabling the constituents of a mixture to be partially separated, the dyed hanks often assuming approximately the

different shades of the constituent colouring matters. The separation is only a very imperfect one, but is further aided by carrying out the test in neutral, acetic acid, and strongly acid, baths for wool, and with gradual addition of Glauber's salt to the dyebath in the case of direct cotton dyestuffs.

Preliminary tests.

Where the character of an unknown dyestuff is to be investigated, the following preliminary dye-trials may be made :

1. Boil a solution of a small quantity of the dyestuff acidified with acetic acid, with small pieces of woollen and of tanned cotton yarn together in a test-tube for a minute or two, then decant, and wash with cold water. Under these circumstances, basic dyestuffs mainly colour the tanned cotton, whereas acid and substantive colours dye the wool, leaving the tanned cotton much less tinted.

2. Boil a solution of the dyestuff to which a little Glauber's salt has been added with a small piece of unmordanted bleached cotton yarn for a few minutes, decant, wash two or three times with cold water, heat almost to the boil with a small quantity of water, after which again rinse once with cold water. Substantive colours dye the cotton a full shade, which does not lose much of its colour when heated nearly to the boil with a small amount of water for half a minute.

According to the result of the above two tests further elaboration is possible, as follows :

(1) If an acid colour has been found, further trials may be made to dye wool in a neutral bath with addition of Glauber's salt, also in a bath made faintly acid with acetic acid, and in a bath strongly acidified with sulphuric acid. Among the colours which dye wool in a neutral bath may be mentioned the Sulphoncyanines and Sulphon Cyanine black, also the similar Alphanol blues and blacks of Cassella, Wool Fast black B (Badische), Indocyanines (Berlin), Alkali violets and blues, and the substantive colours in general ; also many acid colours which are also used in wool dyeing from a strongly acid bath, such as the Fast and Naphthol reds, Orange II, Wool green S, Patent blue, Acid violets, etc. Attempts may also be made to prepare dyeings according to the one-bath or after-chroming method. With many of the after-chrome colours, the direct is totally different in shade to the chromed dyeing ; thus the red Chromotropes (Höchst)

become blue-black on after-chroming. This is often a valuable indication of the nature of the colour under investigation.

(2) If a substantive colour has been found, further trials may be made to discover whether the dyestuff is one intended for the diazotising and developing process, or for after-treatment with formaldehyde, metallic salts, etc.

In case the dyestuff is in the form of a paste, it may be, but is not necessarily, a mordant colour, and trials may be carried out to dye it on chrome mordanted loose wool, also on calico printed with various mordants.

If the dyestuff is not soluble in the usual solvents an attempt is made to dye the colour on cotton yarn in a boiling bath containing sodium sulphide and common salt. Apart from the Sulphur dyestuffs, a number of the vat dyes, including Hydron blue, olive and brown, also Thioindigo red, Indanthrene yellow and violet BN extra, would dye the cotton under these conditions. In order to confirm the presence of a Sulphur dyestuff, the dyeing is well washed, boiled out with water several times, then once with 10 per cent. caustic soda solution to remove any finely divided sulphur present, again well washed with water, dried, and a small cutting heated with stannous chloride solution strongly acidified with hydrochloric acid. The top of the test-tube is covered with a close-fitting cap of filter-paper in the middle of which one drop of lead acetate solution has been placed. After warming, the tube is allowed to stand some time. If a Sulphur dyestuff is present, the filter-paper, especially the under side of the lead acetate spot, will be coloured brown. With the exception of Hydron blue and a few sulphurised vat dyestuffs, the vat colours do not give this reaction. A further portion of the dyeing is immersed in dilute bleach liquor and allowed to stand. A rapid discharge of the colour indicates the presence of a Sulphur dyestuff. In this manner Hydron blue may be distinguished from an ordinary Sulphur blue, as its dyeing remains practically unaltered in the bleach liquor. Finally the reduction test with alkaline hydrosulphite, described later, may be performed on the sample of dyestuff, in order to determine whether it is a vat colour.

Having decided by means of the above tests to which dyeing group the unknown dyestuff belongs, it is desirable as a further guide to its identification, to determine the chemical relationship of the colour. This may be accomplished with the aid of a scheme worked out by Weingärtner in 1887, and later further elaborated and

extended by A. G Green. (For tables see "Manual of Dyeing," by Knecht, Rawson and Löwenthal, Vol. II.)

The use of this scheme is simplified by having previously determined the dyeing group to which the unknown colour belongs, as already described.

Group I. Dyestuffs soluble in water.

(a) *Basic dyestuffs.*

A basic dyestuff found in the dyeing tests may be confirmed by just acidifying a dilute solution with acetic acid, adding a small amount of tannic acid solution, when a coloured precipitate is formed. Dyestuffs of the Gallocyanine class, also the Triphenylmethane mordant colours used in printing only give a finely divided precipitate slowly with tannic acid solution.

A moderately strong solution of the dyestuff is reduced with zinc dust and dilute hydrochloric acid. The zinc is allowed to settle a moment, and the clear liquor poured off on to a piece of filter-paper, which is suspended to drain.

I. In case the original colour returns immediately on exposure to air, the basic dyestuff belongs to the class of Azine, Oxazine, Thiazine or Acridine colours. Of these, Thiazine dyestuffs may be detected by heating to redness a small amount of the powdered dyestuff mixed with pure lime in a crucible, dissolving the cooled mass in hot dilute nitric acid, filtering if necessary, and testing the filtrate for sulphate with barium chloride solution. Acridine colours, which are mostly orange and yellow, dissolve in concentrated sulphuric acid with a bright green fluorescence. The chief members of these four "Azine" groups are :

Red. Safranine, Rhoduline red and Brilliant Rhoduline red B (Bayer), Magdala red (Durand), Neutral red (Cassella), Pyronine and Acridine red (Leonhardt).

Orange and Yellow. Phosphine, and the related Patent Phosphine (Soc. Chem. Ind.), Paraphosphine and Diamond Phosphine (Cassella), Rheonine (Badische), Flavophosphine (Höchst), Aurophosphine (Berlin), also Acridine orange NO (Leonhardt), Acridine yellow (Leonhardt) and Benzoflavine (Griesheim-Oehler).

Green. Azine green (Leonhardt).

Blue. Methylene blue, New Methylene blue N (Cassella) Thionine blue (Höchst), Gentianine (Geigy), New blue or Meldola's blue, Muscarine (Durand), Nile blue A (Badische), New Methylene blue GG (Cassella), Capri blue (Leonhardt), Cresyl blue, Brilliant Cresyl blue 2 B (Leonhardt), Neutral blue (Cassella), Basle blue R and 2 B (Durand), Indazine M

(Cassella), Metaphenylene blue (Cassella), Paraphenylene blue (Durand), Toluylene blue (Griesheim-Oehler), Indamine blue (Höchst) and Methyl Indone B and R (Cassella).

Violet. Mauve, Neutral violet and Fast Neutral violet (Cassella) Tannin heliotrope (Cassella) and the similar Safranine MN (Badische), Paraphenylene violet (Dahl), Prune pure (Sandoz).

II. If the original colour returns very slowly or not at all on exposure to air, but returns on spotting with 1 per cent. chromic acid solution, the dyestuff belongs to the class of Basic Phthaleins and Triphenylmethane colours. The former yield powerfully fluorescent aqueous solutions, and the colour of Rhodamine B in the above test returns much more quickly than that of Magenta; with Victoria blue B a much greener shade than the original is obtained on reoxidation. The chief dyestuffs of this group are :

Red. Diamond Magenta, and the impure brands Cerise, Grenadine, Cardinal, Russian red, etc., Rhodamine B, G, 3 B, and 6 G (Badische and Soc. Chem. Ind.), Irisamine G (Cassella), Rhodamine S (Badische and Soc. Chem. Ind.).

Green. Methyl green, Malachite green, Brilliant green, Victoria green 3 B.

Blue. Victoria blue B and 4 R and Victoria pure blue B (Badische), Victoria blue R (Badische), Night blue (Badische and Soc. Chem. Ind.), Glacier blue (Soc. Chem. Ind.), Setoglaucine, Setocyanine, and Setopaline (Geigy), Turquoise blue G and 2 B (Bayer).

Violet. Methyl violet R to 5 R, Methyl violet B and 2 B, Methyl violet 6 B, Crystal violet (Badische and Soc. Chem. Ind.), Ethyl purple (Badische and Soc. Chem. Ind.).

III. If the original colour does not return even on the addition of chromic acid, the dyestuff may be one of a number of basic Azo dyestuffs such as Chrysoidine, Bismarck brown, Tannin orange (Cassella), New Phosphine, Azo Phosphine, etc. The yellow Thioflavine T (Cassella) belongs to the Thiobenzenyl group which are only reduced with great difficulty. The reduced solution of Auramine on filter-paper gives a fine violet when the paper is warmed over a flame until dry. The Safranine-Azo dyestuffs Indoine blue and Naphthindone yield the pink colour of Safranine immediately on exposure to air after this reduction test.

The isolation of the basic dyestuffs for further examination may also be effected by making the aqueous solution alkaline with caustic potash and shaking out with ether. The bases are liberated and pass into solution in the ether. The latter

is now washed once or twice with very dilute caustic soda and then with dilute acetic acid 5 per cent., which extracts the bases from solution in the ether. The acetic extract can now be concentrated for further examination. Differences in the basicity of these dyestuffs may be made use of in their separation as follows : The aqueous solution is first extracted with ether. Such colours as Chrysoidine, Bismarck brown, Rhodamine S, Victoria blues B, R, and 4 R, etc., are already dissociated in aqueous solution and the base passes into the ether. One per cent. ammonia is now added and the extraction continued with fresh ether. The weak alkali liberates the bases of Induline, Oxazine and Acridine dyestuffs which are extracted. The dilute ammonia is followed by strong ammonia which liberates Magenta, and finally by caustic potash which sets free the Safranine bases, and these can be extracted in their turn. This separation is naturally only an approximate one.

(b) *Acid and Substantive Dyestuffs.*

The aqueous solution is reduced with zinc dust and ammonia, and poured on to filter-paper.

1. If the solution is decolorised, but the colour returns on exposure, this indicates sulphonated Azines, Oxazines, Thiazines, etc., including Soluble Indulines and Nigrosines, Azo-Carmine (Badische) and Rosinduline (Kalle), Thio-carmine (Cassella), soluble Gallocyanines (leuco or bisulphite compounds), Phenocyanines, Gallo Navy blue, Gallophenine, etc., or sulphonic acids such as Delphine blue, Gallanil indigo and violet, Brilliant Alizarin blues R, G, B, 3 R (Bayer), Indochromine (Sandoz), Indocyanine (Berlin), also Indigo Carmine. The Brilliant Alizarin blues and Indigo Carmine give yellow solutions on reduction.

II. If original colour does not return spontaneously, but only on addition of chromic acid and exposure to ammonia vapour, a further separation is effected by acidifying the dye-solution and shaking out with ether :

1. The ether extracts the colour-acid, leaving the aqueous solution almost colourless. Indicates Phthaleins and Aurines, mostly giving highly fluorescent solutions, including Uranine, Chrysoline, Eosine, Erythrosine, Phloxine, Rose Bengal, Cyclamine, Aurine, Coralline. To further identify, test original colour for chlorine, bromine and iodine, by calcination with pure lime, followed by the usual qualitative tests for chloride, bromide and iodide.

2. Ether remains colourless.

Dyestuff belongs to the large class of sulphonated Triphenylmethane colours, which includes such important

dyestuffs as Acid Magenta, Acid greens, Cyanole Fast green G (Cassella), Naphthalene green V (Höchst), Erio green (Geigy), Light green S. Wool green S, Neptune green, Aglama green (Badische), Guinea green (Berlin), Fast green bluish (Berlin), etc.; also Patent blue (Höchst), Erioglaucine and Eriocyanine (Geigy), Cyanole and Tetracyanole, Brilliant Milling blue and green (Cassella), Neptune blue (Badische), Brilliant Acid blues, Acid violets, Formyl violet, Alkali and Soluble blues, Brilliant Wool blues. Also the important **Triphenylmethane** mordant dyestuffs of Geigy and Bayer, viz., Chrome violet, Eriochromazurol (Geigy), the Chromoxan colours (Bayer).

III. In case the solution is decolorised in this reduction test, and the colour does not return, even on oxidation of the reduced liquid on filter-paper with chromic acid, then this points to the presence of those groups of dyestuffs which are destroyed on reduction, viz., the Nitro-, Nitroso-, Azo-, and Hydrazine colours.

The Nitro-dyestuffs, other than picric acid, which is almost obsolete as a dyestuff although employed in the production of important afterchrome dyestuffs such as Metachrome brown (Berlin), include Naphthol yellow S, the Nitro-Azo colours, Azoflavine (Badische) and Indian yellow (Bayer), also the above Metachrome brown derived from picramic acid. These dyestuffs usually deflagrate when heated on platinum foil.

The Nitroso-dyestuffs, principally used in calico-printing in conjunction with iron and chrome mordants, are usually in the form of pastes sparingly soluble in water. They include Fast green, which is dinitrosoresorcin, also Viridone FE (Höchst), which yields a far brighter green than dinitroso-resorcin on iron mordant, and Chrome bistre NO (Höchst), also used in printing, giving deep brown shades on chrome mordant. The older Gambines (Holliday) and Dioxine (Leonhardt) seem to be but little used. This class also includes an acid dyestuff, Naphthol green B (Cassella), of great fastness to light, and employed in dyeing carpet yarns. A colour belonging to this group can be detected by Liebermann's test for nitroso- compounds. A very small amount is warmed together with some phenol and conc. sulphuric acid, after which the mixture is cooled, diluted with water and made alkaline with caustic potash. An intense blue coloration is obtained.

Besides the small groups of Nitro- and Nitroso-dyestuffs, the Hydrazine colours, mostly yellows, and including **Tartrazine, Fast light yellows (Bayer), Flavazines (Höchst).**

Xylene light yellow (Sandoz), etc., the extensive group of Azo-dyestuffs are also destroyed in the reduction test with zinc dust and ammonia. The dye-trials previously performed will have shown whether the Azo-dyestuff, if present, is an acid or substantive colour. A closer identification can in this case only be attained by use of tables giving the reactions of individual dyestuffs.

Among the acid and substantive colours are several groups which are not decolorised by zinc dust and ammonia. Perhaps first in importance among these are the Acid and Soluble Alizarin dyestuffs (bisulphite compounds). All these on reduction yield a red to brown vat, and the reduction in these cases is preferably carried out in the cold. The Acid Alizarins are generally of outstanding fastness to light and include Alizarin Saphirole B and SE, Alizarin Astrole B and G, Alizarin sky blue B, Alizarin Uranole R and B, Alizarin Irisole R, Alizarin Rubinole R, GW, 3 G, 5 G, Alizarin Cyanine green G extra and 3 G, Alizarin Viridine, Brilliant Alizarin Cyanine 3 G and 2 G, Alizarin blue black B and 3 B (Bayer), also Cyananthrol R, Anthraquinone blue SR extra, Anthraquinone violet and Anthraquinone green GXN, Anthracene blue SWGG (Badische), Alizarin Direct blue B, Alizarin Direct green, and Alizarin Direct violet, Acid Alizarin blue GR and 2 B (Höchst). If the group test point to an acid Anthraquinone colour (red-brown vat on reduction), the shade obtained on woollen yarn in the dyeing test will enable the exact colour to be singled out from the above list in most cases. Also use may be made of the fact that Alizarin sky blue B (Bayer) and Anthraquinone blue SR extra (Badische) contain combined bromine in the molecule for the detection of these two colours.

This class includes Alizarin S, which dyes on chrome-mordanted wool, or according to the afterchrome process, also the soluble bisulphite compounds, Alizarin blue S, Indigo blue S, green S (Badische), also Coerulein S and Alizarin black S. These compounds form dark pastes or liquids with the smell of sulphur dioxide, which is evolved when a sample is acidified and warmed. Here again the shade obtained in the dyeing tests is of great assistance in the identification of the exact colour.

A further group of dyestuffs which are reduced very slowly or not at all by zinc dust and ammonia are the Thiobenzenyl colours, which remain yellow on reduction. These include the substantive yellows Thiazol and Clayton yellows, Mimosa, Primuline, Oxyphenine, Diamine fast

yellow B, FF, Chloramine yellow, Thioflavine S, and also the acid dyestuff Quinoline yellow, not belonging to the latter class. The Thiobenzenyl-Azo-colours, Erica (Berlin), Brilliant Geranine (Bayer), etc. (direct cotton dyestuffs), also give on reduction a yellow liquid, due to destruction of the azo-group.

Group II. Dyestuffs insoluble in water.

A small sample is warmed with 5—10 per cent. caustic soda solution

I. The colour does not dissolve.

Another sample is tested for solubility in alcohol:

(a) Dyestuff soluble in alcohol, solution not fluorescent. This sub-group includes Spirit Indulines and Nigrosines belonging to the Azine group—reduction test with zinc dust and a few drops of conc. ammonia in alcoholic solution, colour returns on pouring reduced solution on filter-paper; also Spirit blue (triphenylmethane), colour returns on oxidation on filter-paper with a 1 per cent. solution of chromic acid in glacial acetic acid. This group also includes many of the oil-colours, such as Soudan red (Fast red T (Geigy)), Oil reds B and G, Oil blacks, Typophor red, carmine and violet (Badische), etc., for the most part Azo-colours destroyed in alcoholic solution by alkaline reducing agents.

(b) Dyestuff soluble in alcohol, solution fluorescent. Colour present is one of the Spirit Eosines, Cyanosine, or Magdala red (rarely met with).

(c) Dyestuff insoluble in alcohol.

This group includes the numerous vat dyestuffs, which may be further classified into three principal groups: 1. Indigoid; 2. Anthraquinone; 3. Other vat dyestuffs.

1. The Indigoid dyestuffs include Indigo, Brilliant Indigo dyestuffs (Badische), Ciba colours (Soc. Chem. Ind.), Helindone colours (Höchst), which are identical with the Thioindigo series (Kalle), and also a few of the Algol dyestuffs of Bayer. On reduction with a warm 10 per cent. solution of Hydrosulphite conc. powder made strongly alkaline with caustic soda these dyestuffs give yellow-coloured vats. They are also soluble to a greater or less extent with characteristic colours (sometimes fluorescent, especially the reds) in boiling benzene, pyridine, and glacial formic and acetic acids. For this latter test a sample of the paste is dried in the air-oven at 120°C.

2. The Anthraquinone vat dyestuffs include the Indanthrene and Algol groups.

In this case the reduction product or vat with warm alkaline hydrosulphite solution is with most of the dyestuffs, excepting the blues (which yield blue leuco-products), very characteristic, being deeper and in most cases totally different in shade—usually deep blue, violet, red or orange—from the dyestuff or the dyeing produced with it.

The Anthraquinone colours are insoluble or only very slightly soluble in boiling benzene, pyridine, and glacial acetic and formic acids.

3. Other vat dyestuffs. These include the vat dyestuffs prepared from anthraquinone, benzanthrone and carbazol derivatives by fusion with sulphur or polysulphide, and include Hydron blue, olive and brown (Cassella), (the two latter apparently identical with Indanthrene olive and brown), also probably some of the Cibanone colours, Cibanone black (Soc. Chem. Ind.). The reactions of these dyestuffs resemble those of the Anthraquinone group, but are less characteristic. Hydron blue also yields a yellow vat, whereas Hydron olive and brown resemble Sulphur colours in being partly or wholly discharged by immersion of the dyeings in bleach liquor (hypochlorite). The identification of the vat dyes individually may be facilitated by also noting in addition to the above tests the shade obtained when the sample is dyed on cotton yarn; also the coloration, which is often very characteristic, obtained by solution in concentrated sulphuric acid.

The test which has been proposed for identifying these colours on the fibre, viz., heating in a dry tube and noting the colour of any vapour or sublimate produced, does not appear to be very characteristic for colours other than Indigo and its halogen derivatives (violet vapours), but as a general test for the Indigoid vat colours it is somewhat uncertain. The Brilliant Indigo and Ciba blue dyestuffs (brom- and chlorobrom-Indigo) may be further distinguished from Indigo by heating with pure lime, dissolving the cooled mass in boiling dilute nitric acid, and testing for chloride and bromide in the filtrate. In this case the Indigo may advantageously be heated in a porcelain boat in a hard glass tube, and the vapour carried by a stream of air or oxygen over a layer of red-hot lime.

II. The colour is soluble in caustic soda.

The reduction test with zinc dust and ammonia is now carried out on a fresh sample.

(a) A brown vat is obtained which when poured on to filter-paper reoxidises to the original colour. This group includes Gallein, Coerulein, Gallocyanine, Gallamine blue, Gallo-flavine, Resoflavine, Alizarin blue and black, Anthracene blues and Alizarin Cyanines, all dyestuffs which are generally met with in the form of 20 per cent. pastes. Alizarin blue gives a bright red reduction product.

(b) A brown vat is obtained, but on pouring on to filter-paper the original colour does not return, but the colour of the alkaline salt of the dyestuff is obtained, (e.g., with Alizarin, violet). On spotting with dilute sulphuric acid on the filter-paper, this yields the original colou.. except with Alizarin orange. This group includes Alizarin, Anthrapurpurine, Flavopurpurine, Alizarin Bordeaux, Alizarin orange and Anthracene brown. The reduction test with Alizarin dyestuffs, as noted previously in considering the Acid Alizarins, is best performed cold to avoid over-reduction.

In this group may also be included the pigment Azo-dyestuffs such as Lithol red R, Lithol Fast scarlet (Badische) which are soluble in boiling alcohol and also in hot alcoholic ammonia.

It is to be noted that in most cases it will only be necessary to carry out a selection of the tests described before the dyeing group and chemical relationship of the unknown colour have been ascertained, when it will generally be a question of quite a small number of possible individual dyestuffs. For more exact identification at this stage, use may be made of the various tables of the reactions of dyestuffs with various reagents, previously referred to. Such tables have been compiled by Schultz and Julius, "Tabellarische Uebersicht der künstlichen Farbstoffe."

B. On the Fibre.

The investigation of dyestuffs on the fibre presents an even more difficult problem than the examination of the dyestuffs themselves, for two reasons. In the first place, the majority of dyed shades have generally been produced with a number of dyestuffs, often belonging to different classes, both chemically and from the dyeing standpoint. Secondly, the large number of methods now in use for after-treating dyeings with the object of fixing the dyestuff more firmly on the material renders it impossible in many cases to strip the dyed fabric and examine the resulting dye-solution according to the methods described in Section A.

It is only necessary to identify the chemical class or classes

of the dyestuffs which have been employed and to which dyeing groups they belong in order to be able to select dyestuffs to produce the same shade and fastness as the dyeing to be matched. In certain cases it is, however, essential to determine the actual dyestuffs used in obtaining a particular shade.

Presence of Mordant.

It is first ascertained whether the dyestuff has been fixed on the fibre with the aid of a mordant. The following metals may be present : Lead, copper, antimony, tin, aluminium, iron, chromium, titanium, zinc, manganese, nickel, cobalt, calcium, and magnesium.

As a rule lead is only present on cotton dyeings, as Chrome yellow or Chrome orange, alone or in combination with an Indigo ground to produce a green shade.

Antimony is only present on cotton dyeings, in conjunction with basic dyes. Manganese oxide is used in producing Manganese bistre on cotton. Calcium may be present as an assistant mordant in the case of many Alizarin dyeings and prints on cotton.

The other metals mentioned are employed in the form of their salts as mordants and fixing agents in connection with various classes of dyestuffs on both wool and cotton.

Before the analysis of the ash is undertaken it is advisable that the material to be investigated should be thoroughly washed in hot water.

As the amount of metallic oxide present on the material may be very small (especially is this the case with coppered dyeings on wool and cotton materials), a large piece of the dyed material is cut into small pieces, and packed into a large porcelain crucible, which is then covered with the lid, and heated, at first gently and then afterwards more strongly up to a bright red heat over a Méker burner. When decomposition is complete, the lid is removed, and the bulk of the carbonaceous matter allowed to burn away. Finally, in order to get rid of the last traces of carbon, the crucible is cooled, a small amount of potassium chlorate is added and again heated. The residue is allowed to cool, and is then warmed with small amounts of aqua regia, the mass being broken if necessary with a glass rod and each extract decanted into a porcelain dish. The extracts are diluted with water, raised to the boil, and filtered, and the residue extracted with small amounts of boiling water. The extract is then evaporated almost to dryness, and the residue dissolved in a very small amount of water, and analysed according to the usual scheme of qualita-tive analysis.

In case the residue is insoluble in aqua regia, it may contain the oxides of tin, aluminium, chromium, iron, or titanium, which are practically insoluble in acids after strong ignition, and remain in the residue after the treatment with aqua regia. Any such residue is examined according to the usual analytical methods. (See "Qualitative Analysis," Vol. I.)

The filtrate is made alkaline with ammonia, any iron present filtered off, acetic acid added until the solution is faintly acid, and then a few drops of potassium ferrocyanide solution added. The production of a reddish-brown precipitate or coloration indicates the presence of copper.

In testing for iron, it is to be remembered that all wool dyeings give the reactions for iron to some extent due to the presence of combined iron oxide in the natural wool fibre.

In case the presence of a mordant is detected an indication is immediately obtained of the nature of the dyestuff present on the wool or cotton material; the shade is also taken into consideration. The presence of chromium in wool dyeings indicates Alizarin dyestuffs on chrome mordant or one of the very numerous after-chrome colours. As a general rule the presence of chromium in cotton dyeings indicates after-treated substantive dyeings, or possibly Alizarin blue dyed on cotton yarn. In case lead is present with chromium, the presence of Chrome yellow is probable. Copper on dark-blue wool dyeings probably indicates an Indigo ground topped with such coppered colours as Erio fast purple (Geigy), Omega claret (Sandoz), Topping violet (Badische), etc.

Copper on cotton dyeings indicates after-coppered substantive or Sulphur colours. Iron on wool dyeings in large amount indicates Logwood black. Iron on cotton dyeings also indicates Logwood black or Alizarin violet.

Iron and chrome together on cotton may indicate mineral khaki, alone or topped with Sulphur colours. Manganese is present as Manganese bistre.

Iron oxide on fawn or biscuit dyeings indicates that these are due to Iron buff. Iron oxide on blue cotton dyeings may indicate the presence of Prussian blue.

Antimony on cotton dyeings indicates the presence of basic dyestuffs.

Other metals (tin, aluminium, zinc, nickel, cobalt, iron, and chromium, and in rare cases copper) would be met with in fast calico prints made with Alizarin and Nitroso dyestuffs.

In case tin is present in woollen dyeings : scarlet indicates cochineal ; bright lemon yellow, green, etc., dyeings, probably Persian berries, weld, etc., alone or in combination. Alumina in conjunction with scarlet dyeings on wool, Alizarin red, etc.

Precautions must, however, be taken before correct conclusions can be drawn from the presence of metallic oxides on textile materials. Thus alumina is often applied as a waterproofing material to both cotton and woollen goods, iron salts and tannin are employed to cover burls in black woollen piece goods, etc.

Having determined the nature of any mordant, the procedure depends largely on whether cotton or wool dyeings are under examination :

1. Dyeings on Vegetable Fibres.

The various substantive Azo-dyestuffs on cotton, also after-treated and developed according to the various methods, are quickly decolorised when boiled with a dilute solution of titanous chloride (Knecht). Primuline red is discharged to yellow. Paranitraniline red is decolorised on boiling for two minutes, α-Naphthylamine claret requiring longer. The simple undeveloped thio-benzenyl dyestuffs (all yellow or orange) are unaffected by this reagent. Most basic colours dyed on tannin and antimony mordant are destroyed, and the material is left of a dull yellow brown colour due to titanium tannate. With a few colours, *e.g.*, Rhodamine, Thioflavine T, etc., the colour returns on rinsing thoroughly or on immersion in dilute hydrogen peroxide. The Sulphur colours rapidly turn brown or of a drab colour, and hydrogen sulphide is evolved. The original colour returns on washing and exposure to air, or on treatment with dilute hydrogen peroxide. Aniline black also becomes a drab shade, but the black returns on washing and exposure. Indigo is at first converted into Indigo white, but on continued boiling is further reduced and completely destroyed. This test can thus be used for detecting sulphur colours on cotton in presence of Indigo. Prussian blue is instantly decolorised by titanous chloride, but the colour returns on washing in water and exposure to air. Iron buff is quickly reduced and removed as ferrous salt. Turkey red (Alizarin) becomes a maroon in consequence of formation of the titanium lake of Alizarin.

Titanous chloride can also be used for the detection of mixed dyeings. For example, cotton dyed green with Direct Sky blue and Chrysophenine on careful reduction turns blue owing to complete destruction of the yellow, whilst the blue remains unaffected under these conditions.

G. E. Holden (*Journ. Soc. Dyers and Colourists,* 1909, p. 47) recommends titanous chloride as a useful reagent for the detection of colours dyed on cotton. As further tests, he

immerses portions of the dyeings to be investigated in cold chloroform, and also in bleaching powder solution (5° Tw.) to which dilute acetic acid is gradually added.

	Titanous chloride.	Bleaching Powder Soln. (5° Tw.) and acetic acid.
Algol blue CF	Garnet	Green
Algol blue 3G	Dull drab	Gradually discharged.
Algol dark green B	Reddish brown	Light yellow brown.
Algol green B	Reddish blue	Discharged.
Algol red B	Brown	Gradually bleached to salmon shade.
Alizarin blue	Dull black	Discharged.
Alizarin red	Maroon	Discharged.
Azo pink BB	Discharged	Discharged.
Bromindigo FB	Olive	Weakened in shade.
Chloranisidine	Discharged	Very slowly discharged.
Ciba blues	Olive	Weakened in shade.
Ciba red B	Discharged	Unaffected.
Ciba violet B	Discharged	Gradually lighter in shade.
Ciba violet R	Discharged	
Helindone red 3B	Dull violet	Unaffected.
Helindone red 3B and Indigo	Duller violet	Red violet.
Indanthrene blue BO	Reddish brown	Blacker in shade.
Indanthrene blue BT	Black	Blacker in shade.
Indanthrene blue RC	Garnet	Bluish green.
Indanthrene blue RS	Maroon	Green.
Indanthrene claret G	Brown	Becomes gradually browner.
Indanthrene green B	Garnet	Dull brown.
Indanthrene red R	Reddish brown	Becomes a more brick-red shade
Indanthrene violet R	Garnet	Duller in shade.
Indanthrene violet RT	Maroon	Redder in shade.
Indigo blue	Yellow tint	Discharged
Paranitraniline red	Discharged	Unaffected.
Paranitroorthoanisidine	Discharged	Unaffected.
Thioindigo red B	} Practically discharged	Slowly lighter in shade.
Vat red B		
Vat red B and Indigo	Gradually bluer, then discharged	Red colour.

As a rule, direct (substantive) dyeings, direct dyeings diazotised and developed, coupled with paranitraniline, after-treated with formaldehyde, metallic salts, etc., basic, Sulphur, Alizarin, and mordant dyeings on cotton give no coloration with the cold chloroform. They are further distinguished by boiling a small pattern with dilute titanous chloride.

All direct and after-treated direct dyeings are decolorised with the exception of the Thiobenzyl group (reduced to yellow); basic dyeings are discharged, leaving the fibre the yellowish-brown of titanium tannate; Sulphur dyeings evolve hydrogen sulphide gas (for this test reagent must be boiled just before use), whereas Alizarin dyeings are not as a rule decolorised, except in the case of mordant Azo dyestuffs, Alizarin yellow G, etc.

On boiling with water, direct dyeings bleed and the liquid becomes more or less highly coloured; developed or after-treated direct dyeings do not usually bleed off in boiling water or only slightly.

On the other hand, as a rule the Ice colours and many of the vat colours belonging to the Indigoid and Acridone classes are soluble in cold chloroform giving characteristic colorations, and with some vat dyeings a characteristic fluorescence.

The bleach solution test can be used to distinguish between the various Ice colours on the fibre, Azo pink BB being discharged to a bright yellow-orange, Chloranisidine red only being discharged slowly after a time, whereas p-nitro-o-anisidine on β-naphthol is not affected.

To distinguish between the various Primuline dyeings diazotised and developed with phenol, resorcin, β-naphthol, etc., and also after-treated with hypochlorite on the other hand, the dyeing is boiled with titanous chloride. Developed Primuline dyeings are reduced to bright yellow, which can be diazotised and developed with β-naphthol, to a red. On treatment with hypochlorite, Primuline is reduced to a brownish colour, and cannot be diazotised and developed to a red.

Some basic colours are not insoluble in chloroform; many give more or less deep colorations when not fully fixed. Brilliant green and Malachite green give coloured solutions even when fully fixed. Two other exceptions to the above general rule are Dianisidine blue and Alizarin blue, which are soluble in chloroform, giving violet and blue colorations respectively. Indigo and Ciba blue are soluble, and of the other vat dyes, Thioindigo red B, Indanthrene violets, Indanthrene dark blue BO give highly fluorescent solutions. To distinguish

between Indigo and Ciba blue the dyeing is spotted with strong nitric acid, and after a few seconds immersed in cold titanous chloride solution. Ciba blue undergoes very little alteration during these tests, whereas the Indigo dyeing gives a yellow spot with nitric acid, and the blue colour does not return on immersion in titanous chloride solution.

An extension of Holden's use of chloroform to other chlorhydrocarbons has been suggested by Gowing-Scopes. The dyestuffs to be separated are extracted with these solutions in the following order, being then further separated as suggested below :

A.—*Tetrachlorethylene extract.*—Evaporate and extract with pentachlorethane :
> *Soluble.*—Leaf green, Rhodamine B extra, Sudan III.
> Residue extracted with tetrachlorethane :
> *Soluble.*—Nigrosine (sp. sol.) Victoria blue B.
> *Insoluble.*—Ethyl green.

B.—*Pentachlorethane extract.*—Evaporate and extract with trichlorethylene :
> *Soluble.*—Victoria blue BS, Spirit green II, Methyl violet B, Methyl violet B extra.
> *Insoluble.*—Aniline blue II B.

C.—*Trichlorethylene extract.*—Evaporate and extract with tetrachlorethylene :
> *Soluble.*—Aniline blue BB, Malachite green, Diamond green G, Diamond green B, Auramine OO, Eucrysine RR.
> *Insoluble.*—Chrysoidine, Rosaniline, Metanil yellow extra.

D.—*Tetrachlorethane extract.*—Evaporate and extract with dichlorethylene :
> *Soluble.*—Japan black, Jet black BT, Patent blue A, Neptune blue, Rubin N, Safranine scarlet B, Phenolphthalein.
> *Insolubles.*—Safranine scarlet G

E.—*Dichlorethylene extract.*
> *Soluble.*—Nigrosine G, Methylene blue, Vesuvine OOOL, Spirit scarlet G, Induline scarlet, Bismarck brown.
> *Insoluble.*—Nigrosine (water sol.), Methyl blue, Soluble blue IN, Nicholson's blue, Vesuvine BL, Eosine (yellowish), Eosine (bluish), Cotton scarlet, Indigo carmine, Methyl orange, Fluorescein.

Detection of Hydron blue.

To distinguish Hydron blue from Indigo and Sulphur blue dyed materials, the following tests serve :

1. Hydron blue is not stripped from its dyeings by boiling organic solvents, chloroform, 100 per cent. formic acid, glacial acetic acid, etc., which dissolve Indigo from its dyeings.

2. A small piece of a Hydron blue dyeing immersed in cold concentrated sulphuric acid gives a grey rim in the acid after a short time. Sulphur blue dyeings give a fine violet rim as a rule.

3. Hydron blue and Sulphur blue dyeings evolve hydrogen sulphide on boiling with titanous chloride.

4. Hydron blue dyeings immersed in bleach solution of 5°Tw. remain unaltered ; Sulphur blue dyeings are discharged.

Black dyestuffs.

The behaviour of one or two individual blacks on cotton are notable. On boiling cotton dyed with Logwood black with dilute hydrochloric acid the colour is stripped and the solution becomes reddish-orange in colour. Aniline black and Diphenyl black turn brown on boiling with titanous chloride, and are distinguished from Sulphur black by yielding practically no hydrogen sulphide in this test. To further distinguish between these blacks portions of original patterns are immersed in bleach solution of 5°Tw., and acetic acid gradually added. Sulphur blacks are decolorised, Ferrocyanide Aniline blacks give an olive to green fibre, other Aniline blacks and Diphenyl black become red-brown.

Mordant dyestuffs.

To identify the mordant dyestuffs on the fibre, Holden also recommends immersion in bleach solution of 5°Tw., with addition of acetic acid. After allowing to stand, the liquid is poured off, and the material acidified with cold acetic acid and washed.

Mordant dyestuffs on aluminium mordant are decolorised. To confirm aluminium, the discharged pattern is boiled in a solution of logwood for a few seconds. With alumina mordant a violet-coloured fibre is obtained. Mordant colours dyed on iron mordant are discharged leaving a buff-coloured ground. To confirm iron, the discharged pattern is boiled in a solution of logwood for a few seconds; with iron mordant a black-coloured fibre is obtained.

The reactions of the various vat dyes on the fibre have been investigated by A. G. Green (*J. Soc. Dyers and Col.*, 1910, p. 83).

The following tests serve for the detection of these dyestuffs on the fibre :

1. Coloration with concentrated sulphuric acid.

2. Reaction of the dyeing with bleach solution of 5°Tw., whether discharged or otherwise altered in shade.

3. Reaction of the dyeing on spotting with concentrated nitric acid and subsequent immersion in titanous chloride solution.

4. Reduction with warm alkaline hydrosulphite solution.

5. Effect of heating with small quantities of the following solvents : Benzene, pyridine, 100 per cent. formic acid, glacial acetic acid, cresol, etc.

Of these tests only (1) and a modification of (4) in which an acidified Rongalite solution is employed, have been used by Green in his tables.

Acid, basic and substantive colours (the latter not developed or after-treated) can be stripped from their dyeings on the vegetable fibres, the acid colours by warming with water alone, basic colours by boiling with alcohol acidified with a few drops of hydrochloric or formic acid, and substantive colours by boiling with water or dilute ammonia. These solutions may then be concentrated to small bulk and the dyestuffs identified according to Weingärtner's scheme as described in Section A.

2. Dyeings on Animal Fibres.

Basic dyeings may be stripped by boiling with alcohol acidified with a few drops of hydrochloric or formic acid, acid and substantive dyeings may be stripped by boiling with dilute ammonia. These extracts can then be concentrated to small volume and examined according to Weingärtner's scheme.

Alizarin, mordant, and after-chrome dyeings cannot be stripped in this way, but can be identified by using the tables of reactions of dyestuffs on the fibre referred to later

Indigo on Vegetable and Animal Fibres.

A pure Indigo dyeing is not stripped by boiling with water, alcohol acidified with a few drops of hydrochloric or formic acid, or by boiling dilute ammonia. Hence any acid, basic, or substantive dyes used for bottoming or topping vat Indigo dyeings can be removed by these stripping liquids, and the extracts examined separately. Alizarin, mordant, and after-chrome colours dyed in conjunction with vat indigo on wool cannot be stripped, but the Indigo may be completely removed by extraction with boiling pyridine or cresol as recommended by A. G. Green (" Estimation of Indigo, etc.," *J. Soc. Dyers and Col.*, 1913, p. 229), leaving the ground colour undissolved in most cases. This latter can then be identified by its reactions on the fibre. Direct dyestuffs are only partially stripped by boiling water or dilute ammonia.

Indigo dyeings when spotted with concentrated nitric acid yield the well-known yellow spot, which, however, is also given by many other dyestuffs.

By warming with alkaline hydrosulphite solution, Indigo is reduced to the yellow soluble leuco-compound (salt of indigo-white), and stripped from the fibre.

By cautious heating in a glass tube, medium and full dyeings on cotton of Indigo and halogenated derivatives of Indigo, such as the Ciba blues, yield very characteristic violet vapours.

All Indigo dyeings are stripped when extracted with boiling pyridine. On mixing the extract with water the Indigo is precipitated and may be filtered off, washed, dried, and submitted to the sublimation test, above described, for confirmation.

According to a scheme for the Identification of Colouring Matters on Vegetable and Animal Fibres of A. G. Green (*J. Soc. Dyers and Col.,* 1905, p. 237; 1907, p. 252), which is an adaptation of his modification of Weingärtner's method for the identification of dyestuffs in substance, the chemical class and dyeing relationship of the dyestuffs present are first determined, when in many cases the actual dyestuff can be identified by use of tables of reactions of colouring matters on the fibre. Green's scheme is, in the first instance, only applicable to the determination of the class of dyestuff present, but in many instances this is sufficient to enable the dyestuff to be at once identified.

Tables of reactions of dyestuffs on the fibre have been compiled by various chemists, the most complete perhaps being those of C. Dreher, later amplified by G. Weber, . Knecht, and W. Dürsteler. These are to be found *in extenso* in Lunge's "Technical Methods of Chemical Analysis," Vol. II., Part II) (English translation and adaptation by Keane). Representative tables are also included in Heermann's book, "Koloristische und textilchemische Untersuchungen." These two sets of tables will serve for the identification of a large number of dyestuffs, but are incomplete and do not include a large number of the newer fast substantive, acid, and after-chrome dyestuffs of great importance; also only the early vat dyestuffs are included.

PHYSIOLOGICAL CHEMISTRY.

Examination of Urine.

The physical and chemical characters of urine are, in very many cases, of great importance in making a diagnosis, and their variation furnishes an important guide to the progress of disease. Often only a qualitative examination for glucose is required, and usually information concerning not more than two or three constituents is sufficient. Human urine, even during health is of extremely complex composition, and normally contains :

1. *Inorganic compounds.* Sodium and potassium chlorides; potassium sulphate; sodium, calcium and magnesium phosphates; silicic acid; calcium carbonate; ammonium salts.

2. *Organic compounds.* Urea, uric acid, xanthine, hypoxanthine, creatinine, pigments, ferments (pepsin, trypsin), fatty acids, oxalic, oxaluric, lactic, succinic, glycerophosphoric, thiocyanic, and hippuric acids, aromatic and ethereal sulphates.

3. *Gases.* Nitrogen and carbon dioxide.

Pathological urine in addition to the above may contain : albumin and other proteids, hæmoglobin, methæmoglobin, bile pigments, bile acids, acetone, acetoacetic ether, hydroxybutyric acid, lucine and tyrosine, dextrose, lactose, fats, cystin; various sediments; organised bodies as blood corpuscles, urinary casts and renal epithelium. There may also be present colouring, odorous and other substances, the result of taking medicines.

The quantity of urine secreted daily by a healthy man is on an average 1½ litres of Sp. Gr. 1·015 to 1·025. The composition varies considerably according to diet and exercise. According to Vogel the average is :

Water	...	...	...	1440·0	Phosphoric acid	...	3·0
Insoluble matter	...		60·0	Sulphuric acid	...	2·0
Urea	...	...	...	35·0	Earthy phosphates	...	1·2
Uric acid	...	...	...	0·75	Ammonia	...	...	...	0·65
Sodium chloride	...		16·5	Free acid	...	...	...	3·0

For examination, a sample of the mixed urine passed in twenty-four hours should be taken, but in case this is not available that passed three hours after a meal may be used, the analysis being conducted without delay, as changes take place due to fermentation.

Physical Examination.

Quantity. The amounts of urine passed during the day and night should be noted separately. The total in a state of health averages about 1,500 cc.

Colour. Normal urine is of an amber colour, the colouring matters being urochrome and urobilin. Acid urine is darker than alkaline. It is usually deeper in colour when the amount secreted is lessened and paler when the amount is excessive. A reddish or orange-brown tint may indicate blood, bile or the use of such drugs as rhubarb or senna. Greenish or greenish-black urine may be due to the presence of bile or to the use of such drugs as phenol. A yellowish tint may be caused by bile, pus or fat. The urine may appear blue in typhus or from methylene blue, and may be opalescent from bacilli or suspended matter.

Consistence. Normal urine is a thin aqueous fluid. Bile and sugar make it less mobile, pus gives it a ropy appearance, whilst fibrin causes it to gelatinise.

Odour. Normal urine has an aromatic odour. The presence of ethyl acetoacetate imparts a fruity odour. The administration of turpentine confers a violet-like odour, sandal wood oil and copaiba impart their characteristic odours. Fermented urine is ammoniacal.

Deposit. Normal urine on standing shows a cloud of mucus usually settling to the bottom. It may also contain (1) deposits of free uric acid and urates which are usually reddish or dark brown (" cayenne pepper " and " brick dust ") and dissolve on heating; (2) phosphates (Ca and Mg) which are colourless, flocculent, insoluble on heating, soluble in dilute acids; (3) oxalates, a small deposit insoluble in dilute acids.

Specific Gravity. This may be determined by any of the usual methods. Small hydrometers (urinometers) are made graduated from 1·000 to 1·050, but the graduations for sugar on such should be ignored as the gravity may vary independently of the sugar content. If the temperature is above or below 15°C. the gravity can be deduced by adding 0·0015 to the observed gravity for every degree above 15°C. or subtracting 0·0015 for every degree below 15°C.

Solids. The approximate weight of solids per litre is calculated by doubling the last two of the three decimals denoting specific gravity. Thus urine of Sp. Gr. 1·020 corresponds to 40 grm. per litre (= 4%). The percentage multiplied by 4·375 gives the grains per fluid ounce, in this case 17·5.

Chemical Examination.

The urine is tested with litmus paper. Normal urine is usually faintly acid, but may be alkaline after meals. On standing for some time ammoniacal fermentation takes place, and it becomes strongly alkaline. Alkaline urine is passed in certain pathological conditions of the urinary tract, and strongly acid urine may be passed in febrile diseases, especially acute rheumatism, and after taking certain drugs, such as sodium dihydrogen phosphate.

Estimation of solids. 100 cc. are evaporated in a platinum basin until constant in weight and the residue weighed. Decomposition of the syrupy residue leads to inaccurate results. The solids are from 4·6 to 6·5 per cent.

Ash. 100 cc. is evaporated in a platinum crucible, the residue ignited to carbonise organic matter, extracted with hot water and filtered. The residue and filter are dried and ignited, then the filtrate is added, evaporated to dryness, ignited and the crucible weighed. The ash is 0·5 to 0·6 per cent.

Urea, $NH_2.CO.NH_2.$

The usual method of estimating urea, Hüfner's, is to decompose it and measure the nitrogen evolved. The reagent employed is sodium hypobromite solution prepared as required by adding 1 cc. of bromine to 9 cc. of caustic soda solution (0·4 grm. per cc.). A brine charged nitrometer is a convenient apparatus, and the determination is made by introducing 5 cc. of urine, 10 cc. of hypobromite solution, and 10 cc. of water. Nitrogen is at once evolved (see " Nitrometer," Vol. I) :

$$(NH_2)_2CO_3 + 3NaOBr = 3NaBr + N_2 + CO_2 + 2H_2O,$$
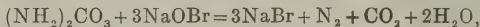
and may be measured as soon as the reaction is completed, the CO_2 being retained by caustic soda. Theoretically 1 cc. of nitrogen at N.T.P. = 0·0027 grm. urea, but in practice only 92 per cent. of the nitrogen is evolved, but it has been found that the increase in volume of the gas due to room temperature (taken as 18°C.) and the vapour tension, almost exactly compensate the loss, and therefore 1 cc. of N = 0·0027 grm. urea under laboratory conditions. If much sugar be present, or if a little glucose be added, the whole of the nitrogen is evolved ; in which case it is usual to deduct 8 per cent. from the volume shown, and take the remainder as 1 cc. N = 0·0027 grm. urea as before. Various forms of ureometers for estimating

urea have been devised with a view to convenience and portability. The "Doremus" and "Victoria" are perhaps the best known.
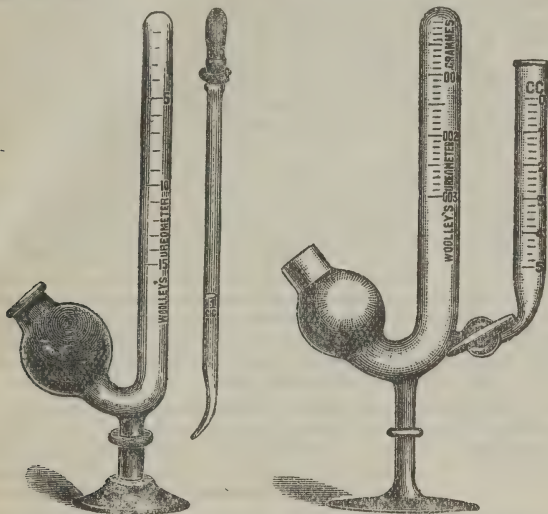
"Doremus."   "Victoria."

Uric acid, $C_5H_4N_4O_3$.

Uric acid occurs normally in urine to the extent of 0·7 per cent., but in pathological urine it is often met with as a sediment, and the crystals may then be recognised under the microscope (see "Sediments").

Tests for Uric acid.

Urine acidified with hydrochloric acid and allowed to stand in a cool place deposits crystals of uric acid; these may be identified by examination under the microscope and the murexide test.

Murexide test. The crystals are placed in a porcelain basin, a drop of nitric acid or a little chlorine water added, and the solution evaporated to dryness on a water-bath. A yellow residue coloured purple-red by dilute ammonia indicates the presence of uric acid.

Estimation of Uric acid.

1. *Hopkins method.* To 100 cc. of the urine enough ammonium chloride is added to make a saturated solution (about 30 grm.), and the mixture is set aside for two hours, stirring occasionally, when uric acid is precipitated as acid ammonium urate. This is filtered off, washed with saturated solution of ammonium sulphate and transferred to 100 cc. of water; 20 cc. of strong sulphuric acid are added, and the liquid, while still hot (about 60°C.), is titrated with N/20 permanganate until the pink colour persists for two or three seconds.

1 cc. of N/20 permanganate = 0·00375 uric acid.

2. *Gowland-Hopkins method.* The uric acid, precipitated as acid ammonium urate as before, is decomposed with hydrochloric acid, allowed to stand for two hours, and the precipitated uric acid dissolved in sodium carbonate and titrated as before. (See *P.J.* i/99, 266.)

3. *Gravimetric.* The acid ammonium urate is decomposed with hydrochloric acid as before; the uric acid is collected, washed with water, then alcohol, dried and weighed. To the weight found 0·001 grm. is added for every cc. of mother-liquor (not including the washings).

4. The hypobromite method ("Gas Analysis," Vol. I) may be used for decomposing the acid ammonium urate. (L. i/07, 14; L. ii/03, 77.)

Glucose (Dextrose).

Normal urine contains small quantities (about 0·25 per cent.) of glucose, but in certain pathological conditions this amount is considerably increased. In *diabetes mellitus* the continued presence of considerable quantities of this sugar is characteristic, and consequently the Sp. Gr. is higher than normal, usually between 1·030 and 1·040, even though the amount of urine passed is greatly increased. In twenty-four hours the volume may be 3000 to 4000 cc. containing 10 to 100 grms. of glucose.

Tests. 1. Fehling's solution is reduced by diabetic urine on boiling. Acetone, lactose, and aldehydes may also be present, and have a similar reaction. This test has been modified by Allen (*Analyst,* xix, 178; *P.J.* ii/95, 307), who adds the copper solution whilst boiling, cools, adds sodium acetate and filters to remove uric acid, phosphates and xanthine. The alkali is now added and again boiled, when cuprous oxide is precipitated before boiling if above 0·25 per cent. be present, or on cooling if less than this proportion.

2. Johnson's or Braun's picric acid test. A saturated cold aqueous solution of picric acid is mixed with an equal volume of normal caustic soda and boiled; a measured quantity of urine is then added, and the mixture again boiled. A deep red colour, due to reduction of the picric to picramic acid, is produced, the depth of colour being proportional to the amount of glucose present. This reaction has been made quantitative by the aid of the " picro-saccharometer," which gives a standard tint. Creatinine, which gives a similar colour, must be removed by treatment with mercuric acetate followed by zinc before applying this test.

3. Phenylhydrazine test. Half a test-tubeful of urine is mixed with 0·5 grm. of phenylhydrazine and 1 cc. of glacial acetic acid, placed in a beaker of boiling water for about half an hour, with occasional shaking, and then allowed to cool. The sugar is then separated as an osazone, and should be further examined under the microscope and the melting point determined. Phenylglucosazone is in yellow acicular crystals, melting at 205°. Lactose occasionally found in the urine of nursing women yields phenyl lactosazone which forms short and broad crystals melting at 200°. Glycuronic acid forms a similar compound, melting at 150°.

4. Indigo or Nitropropiol test. The urine is diluted and mixed with an equal volume of nitropropiol solution (sodium o-nitrophenylpropiolate); on boiling, a blue colour, due to formation of Indigo, is produced, immediately or in a few minutes, according to the amount of glucose.

5. Nylander's Test (modified). A solution of bismuth tartrate (1 per cent.) in caustic soda (8 per cent.) is prepared and warmed with an equal volume of urine. If glucose be present a black precipitate of bismuth suboxide is formed, but lactose and albumen also give positive results. Albumen should be removed by boiling and filtering before applying the test. Lactose may be distinguished by the fermentation test (6). This modified Nylander's test will detect 0·1 per cent. of glucose.

6. Fermentation test. The urine, if necessary, should be slightly acidified with citric acid and then boiled to expel air. The urine is then shaken up with some fresh, active yeast in a special fermentation tube or in an ordinary test-tube, which is inverted in a bath of mercury, carefully excluding air bubbles. After standing a few hours in a warm place a bubble of carbon dioxide collects at the top of the tube if glucose be present. Lævulose, which also reduces Fehling's solution, ferments with yeast, and forms an osazone, is

occasionally found alone in urine, but more commonly with dextrose. The polarimeter will distinguish between lævulose and dextrose. The fermentation test may be modified thus: two flasks of 100 cc. capacity are filled with urine. To one, a piece of crumbled yeast is added, whilst the other is tightly corked. The two tests are allowed to stand for 24 hours in a warm place, when, if glucose be present, carbon dioxide will be evolved by the one containing yeast and may be identified by passing into lime water. The Sp. Gr. of each is then determined, when if over 0·5 per cent. of glucose be present the gravity will be perceptibly lower after fermentation. Each degree of density lost is approximately equivalent to 1 grain of glucose per ounce (0·23 per cent.). (L. ii/06, 1136.)

7. *Optical activity.* Colouring matter and other substances are removed by boiling with lead acetate or mercuric acetate, as described below. The colourless filtrate is then examined with the polarimeter; glucose, if present, will give a dextro rotation; the percentage of glucose may be found by the usual calculation from the observed rotation ($[a]_D = +52·7$).

The presence of glucose must not be assumed unless the urine gives positive reactions with several of the preceding tests. Formaldehyde, which also reduces Fehling's solution, occurs in urine after the administration of such drugs as hexamethylenetetramine (" urotropin "), and it may be tested for thus : to 5 or 10 cc. of sample add 5 drops of 1 per cent. aqueous solution of phloroglucinol followed by 5 drops of 30 per cent. caustic soda solution. A red colour indicates formaldehyde sensitive to 1 in 2,000,000 water and 1 in 50,000 urine, but no colour is given with hexamethylenetetramine.

Estimation. 1. The usual method is that of Fehling, which in ordinary cases gives satisfactory results. Uric acid, creatinine and glycuronic acid must first be removed by boiling the urine with 5 per cent. of its volume of saturated solution of sodium acetate and 25 per cent. of saturated solution of mercuric chloride, filtering out the precipitate and removing the excess of mercury by boiling with zinc dust and filtering. It is usual to place 10 cc. of standard Fehling's solution in a porcelain basin with 40 cc. of water, and to heat the mixture to boiling. Urine from a burette is then run in until the blue colour is just discharged. The presence of the cuprous oxide masks to some extent the end-point, and to obviate this several modifications have been introduced, the chief of which are Pavy's and Gerrard's.

2. Pavy's Method. The standard solution is prepared

by mixing 10 cc. of Fehling's solution with 30 cc. of strong ammonia (0·888) and 10 cc. of 10 per cent. caustic soda solution, and diluting to 100 cc.; the oxidising power of this solution is one-tenth that of Fehling's. As the reduced Pavy's solution is very rapidly reoxidised, air must be excluded during the titration. This is accomplished by conducting the titration in a flask fitted with a three-hole cork; through one hole passes a tube connected with the nozzle of the burette, while the others provide entrance and exit for a stream of coal-gas or hydrogen. A better method is to cover the surface of the liquid with melted paraffin and allow the nozzle of the burette to dip below the surface. The titration is conducted in the same way as before, but as the cuprous oxide is dissolved by the ammonia the end-point is shown by the discharge of the blue colour. A few pieces of porous pot added will prevent "bumping" during boiling.

3. Gerrard's Method. A solution is prepared by decolorising 100 cc. of boiling Fehling's solution with a 5 per cent. solution of potassium cyanide and making the volume up to 500 cc. For use 50 cc. of this solution are mixed with 10 cc. of Fehling's solution, and the urine run in whilst boiling, in the same way as before, the end-point being the discharge of the blue colour. Only the second quantity (10 cc.) of Fehling's solution is reduced by the glucose in the urine. This method is recommended.

Albumin.

Several proteins may occur in urine, but only mucin occurs in normal urine. Serum-albumin and serum-globulin are both included in the term "albumin," and their presence in urine is termed "albuminuria," a condition appearing in acute *parenchymatous nephritis* or Bright's disease.

Tests. The urine is first clarified by filtration, through barium carbonate if necessary, and if alkaline it is made slightly acid with dilute acetic acid.

1. Heat test. The urine is boiled for about a minute; albumin, if present, is precipitated as white flocculi gradually sinking to the bottom on standing. Nitric acid is added when precipitated phosphates will be redissolved.

2. Nitric acid test. The urine is carefully poured on to the surface of an equal volume of concentrated nitric acid. If albumin is present, it is coagulated and forms a white ring on the surface of the nitric acid; small amounts may not appear until after some minutes. Uric acid, urea and resins may also be precipitated, but the first two are soluble on warming, the last in alcohol. Other substances give similar rings. (L. ii/06, 1459.)

3. **Ferrocyanide test.** The urine is acidified with acetic acid, and a 10 per cent. solution of potassium ferrocyanide added; a white precipitate indicates albumin; traces are also precipitated after a short interval.

4. **Salicylsulphonic acid test.** A few crystals of the acid, or a small quantity of solution, added to urine, gives a precipitate or turbidity if albumin is present, and, like the next test, does not cause precipitation of the mucin.

5. **Trichloracetic acid test.** A saturated solution of the acid is carefully poured on to the surface of the urine, when albumin, if present, appears as a white cloud at the junction of the liquids. Alkaloids, which may also be precipitated, redissolve on heating or adding excess of reagent.

Estimation. A simple and convenient method, at the same time a fairly accurate one, is that of Esbach. The urine must be diluted if of Sp. Gr. 1·010 or more and the degree of dilution noted for calculation. The Esbach albuminometer, consisting of a thick glass graduated tube closed by a rubber stopper, is filled up to the mark U with the diluted urine and then to the mark R with the reagent, made by dissolving 10 grm. picric acid and 20 grm. citric acid in a litre of water. After mixing the albuminometer is allowed to stand for exactly 24 hours at a temperature of 15° to 20°C. and the volume of the precipitate read off. The graduations indicate grams per litre in the diluted urine. For accurate determination, the albumin is precipitated by a nitrogen-free reagent, *e.g.* tannic acid, and the nitrogen in the washed precipitate estimated by Kjeldahl's method. The amount of nitrogen multiplied by 6·3 gives the amount of protein.

Albumoses and Peptones.

Albumose is readily detected by first removing the albumin by boiling and filtering, and then adding a saturated solution of salicylsulphonic acid to the clear filtrate; a precipitate indicates the presence of albumoses.

For peptones the albumin is removed as before, and the filtrate is saturated with ammonium sulphate and again filtered. To this filtrate a dilute solution of salicylsulphonic acid is added when a precipitate soluble on warming and reappearing on cooling indicates peptones.

Acetone bodies.

Acetone bodies include acetone, β-hydroxybutyric acid and acetoacetic acid.

Acetone occurs in febrile diseases and cancer and can often be detected by the odour of the urine; in such cases the Sp. Gr. will be considerably decreased. The urine is usually distilled, using a Liebig's condenser, and the first portion of the distillate used for the tests.

Legal's test. Fresh concentrated sodium nitroprusside solution added to the distillate, made slightly alkaline with caustic potash, produces a red colour in presence of acetone, rapidly fading to yellow, which become reddish-violet, then blue on addition of acetic acid.

Lieben's test. To the distillate, made strongly alkaline with caustic potash, add a little iodine solution and allow to stand. Iodoform is precipitated in the presence of acetone; the crystals can be confirmed microscopically and by their odour.

Acetoacetic acid. *Gerhardt's test.* Ferric chloride gives a red coloration discharged by potassium citrate. Salicylic acid and its compounds produce similar colorations, but acetoacetic acid may be removed by boiling for five minutes, and any reaction then will be due to salicyclic acid.

β-Hydroxybutyric acid is found only when acetoacetic acid is present also. It may be tested for by the polarimeter, when sugar has been removed by fermentation; its specific rotation is $[\alpha] = -23\cdot4°$.

Hippuric Acid.

Hippuric acid occurs in normal urine to a very small extent, but in the urine of herbivoræ it is the chief nitrogenous product. Benzoic acid, taken as medicine, is excreted as hippuric acid.

Estimation. A litre of the urine made slightly alkaline with sodium carbonate is filtered and evaporated nearly to dryness. The residue is extracted with absolute alcohol, the alcohol evaporated and the residue acidified with hydrochloric acid. The acid solution is now repeatedly extracted with ethyl acetate, the filtrates united, washed with water, and allowed to evaporate, when hippuric acid crystallises out. This is dried over sulphuric acid and weighed. Fat, if present, may be removed by washing the hippuric acid with petroleum ether.

Creatinine.

This product occurs normally in urine to the extent o 0·2 per cent., and is readily soluble in water.

Test. The addition of a few drops of sodium nitro prusside solution followed by dilute caustic soda to urine produces a burgundy red colour which fades on boiling, bu on the addition of a little acetic acid to the boiling solution Prussian blue is produced.

Determination in Urine.

Folin has adapted the Jaffé colour reaction of creatinine with picric acid and caustic soda to its estimation. A layer of $N/2$ $K_2Cr_2O_7$ solution 8 mm. deep has the same colour as a layer 8·1 mm. deep of a solution prepared from 10 mgm. of pure creatinine, picric acid and caustic soda. The colour of the unknown solution is compared with that of $K_2Cr_2O_7$ solution in a Duboscq colorimeter, and the creatinine calculated, as the colours are directly proportional.

Into a 500 cc. flask are placed 10 cc. of urine, 15 cc. of saturated picric acid solution (12 grm. per litre), and 5 cc. of 10 per cent. caustic soda solution. After standing for at least 5 minutes, the liquid is diluted to 500 cc. with water, and the colour compared with that of $N/2$ dichromate. The dichromate is placed in one cup of the colorimeter and the depth through which the colour is viewed adjusted to 8 mm. by means of the screw and vernier. The tint solution is placed in the other cup, and this side is adjusted with the screw until the colours appear identical.

Example : 10·1 mm. of the solution = 8 mm. dichromate = 8·1 mm. of a solution containing 10 mgrm. of creatinine per 500 cc.

Creatinine in 10 cc. of urine = $10 \times \dfrac{8·1}{10·1} = 8·02$ mgrm.

Indican.

Ehrlich's test. 0·33 grm. of dimethylaminobenzaldehyde is dissolved in 50 cc. of water and 55 cc. of strong hydrochloric acid added. The urine is boiled with an equal volume of this solution, cooled and made alkaline with ammonia: a red colour indicates indican (for estimation see sulphates).

Indoxyl.

An equal volume of hydrochloric acid is added, the liquid shaken, and a drop or two of sodium hypochlorite solution added; a blue colour, extracted by chloroform, indicates indoxyl.

Sodium Chloride.

This is estimated in the usual manner by standard silver nitrate; 10 cc. of urine is diluted to 200 cc. with water and titrated with N/10 silver nitrate, using potassium chromate as indicator. 1 cc. N/10 $AgNO_3$ = 0·00585 grm. NaCl.

Phosphates.

Phosphoric acid occurs in the urine in combination with an alkali or alkaline earth metal; a small amount of phosphorus is in organic combination. Alkaline earth phosphates are precipitated when the urine becomes alkaline through ammoniacal fermentation. Acid sodium phosphate appears in the urine after oral administration, and such urine being acid the earthy phosphates remain in solution. Phosphoric acid is estimated by means of standard solution of uranium nitrate. 50 cc. of urine is made acid with acetic acid and a little sodium acetate (about 1 grm.) added. The mixture is now heated to nearly boiling and the standard uranium solution run in until a drop of the mixture gives a brown coloration with a drop of fresh solution of potassium ferrocyanide. The uranium solution is standardised against a standard solution of sodium phosphate containing the same proportions of acetic acid and sodium acetate. Normal urine contains 0·15 to 0·2% P_2O_5.

Sulphates.

Total sulphuric acid is estimated gravimetrically by precipitating as barium sulphate. 100 cc. of urine, with the addition of 10 cc. of hydrochloric acid, is boiled with a solution of barium chloride; the precipitated sulphate is filtered off, washed, dried, ignited and weighed, and from the weight the amount of total sulphuric acid is calculated.

Ethereal sulphates are estimated by Salkowski's method thus: To 100 cc. of urine an equal volume of solution, containing two parts of saturated solution baryta and one part saturated solution barium chloride, is added, and the mixture is allowed to stand. The precipitate is filtered out, 100 cc. of the filtrate taken (= 50 cc. urine), and hydrochloric acid added in large excess. The mixture is now heated to 100°, and the precipitate collected and weighed, and from the weight this amount of ethereal sulphates is calculated. This amount subtracted from total sulphuric acid gives the sulphuric acid.

Acidity and Alkalinity.

Acidity, due mostly to the presence of acid sodium phosphate, is determined by decinormal alkali, using phenolphthalein as indicator. Each cc. of standard solution

= 0·012 grm. acid sodium phosphate. Acidity is usually reported in terms of the number of cc. of this alkali required for 10 cc. urine, *e.g.* 3 cc. = 3°.

Alkalinity is estimated and reported in a similar manner using standard acid.

Ammonia.

Ammonia is present in normal urine to the extent of 0·30 per cent. by weight. It is estimated by placing 50 cc. of fresh urine, or urine preserved with phenol, in a shallow vessel, adding 20 cc. milk of lime, and placing it under an air-tight bell-jar along with a second dish containing 10 cc. of normal sulphuric acid. After standing for three days the acid is titrated.

A better method is to distil off the ammonia under reduced pressure, when the risk of decomposing the urea is obviated. Malfatti's method utilises condensation of ammonia with formaldehyde. (See *B.M.J.*, i/09, 715.)

Bile Pigments.

Urine containing bile has generally a greenish-yellow colour, and the froth a yellow colour. This occurs in jaundice.

Gmelin's test. A little fuming nitric acid is placed in a test-tube and an equal volume of the urine carefully poured on to the surface. If bile pigments are present a green ring appears at the zone of contact, and below this appear in order, violet, red, and yellow zones. The latter without the green zone do not indicate bile.

Fleischl's modification. The urine is mixed with a strong solution of sodium nitrate and then strong sulphuric acid is carefully added when coloured zones are produced as before. Traces may be detected by adding lime water and passing carbon dioxide through it until the excess of lime is precipitated. The precipitate is collected and treated with fuming nitric acid, when colours as before will be observed.

Other Colouring Matters.

Ehrlich's Diazo reaction. In several pathological conditions some aromatic substance is present which gives a red colour on the addition of diazobenzene sulphonic acid. The test is applied thus : To 5 cc. of urine an equal volume of $\frac{1}{2}$ per cent. solution of sulphanilic acid in 5 per cent. hydrochloric acid is added, then a few drops of $\frac{1}{2}$ per cent. sodium nitrite solution; the mixture is shaken and then made strongly alkaline with ammonia. A positive result is indicated if after shaking the liquid assumes a port wine colour and the froth

is red. Urine passed in cases of tuberculosis, typhoid and measles usually gives this reaction.

Vegetable Colours. After taking drugs containing emodin or chrysophanic acid the urine becomes highly coloured, the colour becoming lighter with acid and deeper with alkalies. Santonin gives similar reactions, but the colour may be extracted with amyl alcohol.

Phenols. Resorcinol, hydroquinone, or phenol may occasionally be present. Such urine becomes dark-coloured on exposure to air.

Examination of Urinary Sediments.

Normal urine, which is at first clear, often throws down a deposit of urates on cooling, and on becoming alkaline through standing, a precipitate of phosphates. Pathological urine may be cloudy at first, and the sediment is then of importance. The urine is allowed to stand for about twenty-four hours in a conical glass vessel. In hot weather a preservative should be added, preferably one-fourth the volume of a saturated aqueous solution of chloroform, to prevent ammoniacal fermentation; but a much better method is to centrifuge, when the sediment will collect in a few minutes. A drop of the liquid from the bottom of the settling vessel is transferred by a pipette to a glass slide and covered with a thin cover-glass. It is then examined under the microscope, using first a low-power and then a high-power objective.

Blood. The presence of blood often imparts a characteristic dark coloration to the urine. Under the microscope the blood corpuscles may be recognised by their appearance. They are biconcave, having an average diameter of 0·0075 mm. ($= 7·5\mu$ or $1/3386$ inch), but on standing they swell up, lose their shape and become disintegrated, which soon happens if the urine be alkaline. In acid urine they retain their shape for a longer period. Their colour furnishes some clue to their source, bright red blood suggesting a lesion near the point of discharge, paler washed-out corpuscles from a point higher up, from the pelvis or even the kidneys.

Confirmation of the presence of blood may be obtained by evaporating a small amount of the deposit to dryness with a fragment of sodium chloride at a low temperature. The residue is treated with a few drops of glacial acetic acid and heated on a slide. When cool, rhomboidal plates of hæmin may be found if blood is present.

Heller's Test. The urine is heated with strong caustic

H 2

potash or soda solution. The presence of blood is indicated by the production of a bottle-green colour, and by the precipitation of phosphates coloured brownish-red by blood.

Pus and Mucus. These occur as white corpuscles somewhat larger than red blood corpuscles, spherical in shape and varying much in size. They often present one or more nuclei which are made more distinct by addition of a drop of dilute acetic acid. A drop of acetic acid is placed on one edge of the cover-glass and a piece of filter-paper applied to the opposite side when the acid will flow underneath. Earthy phosphates are dissolved by acetic acid. A small amount of mucus is present in normal urine, but pus is discharged from suppurating surfaces and urine containing it will give the reactions for albumin. If much pus is present the urine will be viscid, and the sediment, on mixing with an equal volume of strong caustic potash solution, will form a thick viscid mass resembling white of egg.

Epithelium cells. These are much larger than corpuscles, and may be of almost any shape. They have ordinarily a well-defined nucleus, and are often united in groups of three or four.

Casts. These are casts of the uriniferous tubules of the kidney, and usually have a greater length than width; several different kinds occur, and experience alone will enable them to be satisfactorily identified.

Spermatozoa. The source of these bodies is the semen, and usually their presence has no pathological significance. They have a length of 0·050 mm., and appear as colourless rounded bodies with a long flagellum with which they are propelled rapidly forward, but as usually seen they are motionless.

Bacteria, parasites, fungi and fragments of tissue are met with, but these can only be identified by bacteriological methods.

*Crystals.** These may consist of uric acid, urates, leucin, tyrosin, cystin, hippuric acid, calcium carbonate, sulphate or oxalate and earthy phosphates. Most of these have characteristic shapes, and may be recognised by their shapes and behaviour with reagents.

Uric acid crystals are relatively large, frequently visible to the naked eye, the commonest form being rosettes. They may dissolve on heating, and are soluble in alkali.

* Illustrations of urinary sediments will be found in : Long's " Text-book of Urine Analysis," Allen's " Chemistry of Urine," etc.

Urates occur in a great variety of forms, usually in very small crystals. These are little changed by acids, whereas phosphates which are similar in appearance dissolve on addition of acid.

Cystin and cholesterin occur in large thin plates; the former are hexagonal and dissolve in ammonia.

Fat globules, which may come from several extraneous sources, as from a catheter, may be recognised by their appearance.

Foreign matter. A urinary sediment often contains foreign substances which may have become mixed with it accidentally after being voided. The most common of these are hairs, woollen, cotton or silk fibres, starch granules, pieces of vegetable tissue and remains of articles of food.

Urinary Calculi.

Calculi are formed by the deposit of concentric layers of crystallised or amorphous substances on some nucleus, frequently on uric acid. Occasionally they consist of a single substance, such as calcium oxalate or cystin, but usually phosphates, calcium, and uric acid are present.

The calculus may be divided into half and its nucleus recognised. It is then crushed to powder and heated to bright redness on platinum foil; uric acid, ammonium urate and cystin are entirely consumed.

Uric acid is insoluble in water; soluble in caustic potash without evolution of ammonia; soluble with effervescence in nitric acid, the residue on evaporating being red and giving the murexide reaction.

Ammonium urate is soluble in hot water; soluble in caustic potash with evolution of ammonia; dissolves in nitric acid and behaves like uric acid.

Cystin is insoluble in water; soluble in ammonia, the solution depositing the characteristic hexagonal plates on evaporating spontaneously. Ignited with potassium nitrate and sodium carbonate the residue gives the usual reactions for sulphates.

If the calculus leaves a residue after ignition it may be calcium oxalate or calcium and magnesium phosphates.

Calcium oxalate (mulberry calculus) is insoluble in acetic acid, but soluble in hydrochloric acid. The residue after ignition at a low red heat consists of calcium carbonate, and dissolves in hydrochloric acid with effervescence.

The calcium and magnesium phosphates may be identified by the usual tests.

Examination of Blood.

Blood consists of an aqueous fluid, blood plasma, holding in suspension innumerable corpuscles. It contains about 70 per cent. water, is alkaline in reaction, and has Sp. Gr. 1·053 to 1·066. The red colour of blood is due to a pigment in the red corpuscles, hæmoglobin which is a proteid coagulating at about 54°, is optically dextrorotatory, and contains about 0·5 per cent. of iron. It forms a loose compound with oxygen, oxyhæmoglobin, which gives the bright red colour to arterial blood.

Red blood corpuscles. These have an average diameter of 0·0075 mm. (7·5μ) and are discoid in shape with indentations in the two sides. One cubic millimetre contains normally 5,000,000 to 6,000,000 red corpuscles in the case of a man, and about 4,500,000 in the case of a woman. The number is determined by a hæmacytometer, the one commonly used being a Thoma-Zeiss. The blood is diluted by means of special pipettes to 1 in 100 or 1 in 200, and transferred to a microscopic slide having a cell 0·1 mm. deep, and divided into 16 squares, each square being again divided into 16 smaller squares which are 1/20 mm. square. The number of corpuscles in several smaller squares is counted and the average taken.

Average × 4000 × dilution = no. per c.mm.

Many other forms are made and are used in a similar manner.

White corpuscles, leucocytes. These are distinguished from the red corpuscles in having no colour and being more irregular in shape. A cubic millimetre contains on an average 7,000 to 8,000 in adults and 10,000 in children. They are counted in the same way as the red corpuscles, but the blood is only diluted 1 to 10 or 1 to 20. It is desirable to stain before counting to make them more distinct.

Hæmoglobin. This is estimated colorimetrically by diluting the blood with water until it agrees with a standard tint and then noting the dilution. Sir W. R. Gower's hæmoglobinometer or one of its modifications is used.

For permanent mounts, the blood is dried for twelve hours on the slide, stained with a strong alcoholic solution of Eosin, and mounted in Canada balsam.

Alkalinity. This is estimated by noting the amount of N/1000 sulphuric acid required to produce a precipitate. A series of small tubes are prepared containing quantities of standard acid rising by 0·1 cc. om 0·0 cc. to 1·2 cc. of standard acid, the volume in each case being made up to 2 cc. with distilled water. A drop of blood (0·2 cc.) is then added

to each tube, the contents well mixed, and the tube placed in a water bath at 45° for one hour. A slight opalescence appears in all the tubes, but a coarse flocculent precipitate occurs in the tubes containing the larger quantities of acid (0·7 to 0·9 cc.). The appearance of the precipitate is considered to indicate the neutralisation point. (See *J.C.S. Abs.*, ii/10, 317.)

Recognition of blood-stains.

Stains on linen, etc., are usually identified by moistening with a fresh solution of guaiacum resin in alcohol and then adding a drop of ozonic ether: a blue colour indicates blood. If the blood is mixed with a liquid the guaiacum is added and the ozonic ether poured on; a blue ring indicates blood. Sodium perborate and dilute acetic acid may be used instead of ozonic ether, and will show 1 in 50,000.

Ozonic ether is a solution of 1·2% (= 4 vols. O_2) H_2O_2 in ether.

Benzidine dissolved in alcohol and acidified with acetic acid gives a similar colour with blood and hydrogen peroxide. The stain is moistened with normal saline solution, absorbed by cotton wool, and the spot, on treatment with benzidine solution and hydrogen peroxide or sodium perborate, gives the blue colour; said to detect 1 in 200,000.

The stain may be moistened with a drop of acetic acid, and then soaked for one or more hours in a 70—80 per cent. solution of chloral hydrate. Stains 10 or 20 years old are thoroughly extracted by this method, and the resulting solution is used for the ozonic ether or benzidine reaction.

The cloth may be plunged into boiling water, placed on a slide, and a few drops of ammonium sulphide added. Examined microspectroscopically it will show absorption bands of hæmochromogen. If on a weapon or piece of jewellery, it is moistened with ammonium sulphide, scraped off and examined as before.

On treating blood stains with a few drops of water, and then a drop of a solution containing $\frac{1}{2}$ per cent. of mercuric chloride and 2 per cent. of sodium chloride, the blood rises to the top and the corpuscles can be identified microscopically.

Hæmoglobin in solution with a small amount of sodium chloride, evaporated over sulphuric acid to syrupy consistence, then mixed with 15 times its volume of glacial acetic acid and heated on a water bath for several hours, yields, on cooling, flat rhombic crystals of hæmatin hydrochloride with a dark violet colour and lustre.

THE ALKALOIDS.

E. Hope, D.Sc.

The term "alkaloid" includes all nitrogen-containing compounds of a basic nature which can be isolated from the organs of plants or animals. It is sometimes used in a narrower sense, implying basic nitrogenous compounds only of vegetable origin, the nitrogen in which forms a member of a heterocyclic ring.

In the appended tables are included a few substances which do not come under either of the above definitions, but these bodies are either derived by very simple reactions from alkaloids or are synthetic substances with physiological properties similar to those of alkaloids.

Systematic Tests for Alkaloids.

The matter under examination is extracted with an alcoholic solution of tartaric acid. After removal of the alcohol by evaporation and dissolution of the alkaloidal salt in water, the aqueous acid solution is extracted with ether.

Colchicine (and some *Caffeine*) will be extracted.

Colchicine gives a ppt. with tannic acid solution.

The residual aqueous solution is next made alkaline with sufficient caustic soda to set free bases from salts and to redissolve any morphine. On again extracting with ether most of the alkaloids pass into the ether layer.

i. liquid alkaloids :

coniine, nicotine.

ii. solid alkaloids :

(a) a coloration is given by conc. H_2SO_4 : *aconitine, delphinine, emetine, hydrastine, narcotine, papaverine, thebaine, veratrine* (*codeine* gives coloration with hot H_2SO_4) ;

(b) no coloration with conc. H_2SO_4, but coloration with conc. HNO_3 : *brucine, codeine, strychnine* ;

(c) give neither of above reactions : *atropine, caffeine, cinchonine, cocaine, hyocine, hyocyamine, pilocarpine, physostygmine, quinine.*

The residual alkaline layer is made less strongly basic by addition of ammonium chloride, and is extracted with warm amyl alcohol (at $50°$—$60°$C.) or chloroform. The following will be extracted :

morphine (coloration with HNO_3), *narceine* (coloration with conc. H_2SO_4), and *cytisine.*

The residual liquor may still contain :

curarine, solanine, apomorphine, berberine.

These may be extracted by absolute alcohol after evaporation to dryness of the aqueous liquors.

Alkaloid Reagents.

Platinic chloride. 5 per cent. aqueous solution of H_2PtCl_6 gives yellow crystalline or amorphous precipitates, best in presence of alcohol. Alkaloid may be obtained from platinichloride by evaporation with potassium carbonate and extraction.

Auric chloride. 1 : 30 aqueous solution. White, yellow or brown precipitates, generally amorphous and soluble in hydrochloric acid.

Mercuric chloride. 1 : 20 aqueous solution. White or yellowish precipitates, amorphous or become crystalline, insoluble in hydrochloric acid.

Tannic acid. 1 : 10 aqueous solution. White or yellowish precipitates, soluble in hydrochloric acid. Alkaloid recovered by evaporating with litharge and extracting.

Metatungstic acid. Tungstic acid is dissolved in a warm solution of an alkali tungstate, the barium salt precipitated and then decomposed with dilute sulphuric acid, and the filtrate evaporated until crystals separate. The aqueous solution is a delicate reagent for quinine and strychnine.

Picric acid. Aqueous solution gives yellow amorphous or crystalline precipitates from which the alkaloid may be in certain cases recovered by decomposing with baryta.

Bouchardat's reagent (KI_3). 1 part of iodine and 2 parts of potassium iodide in 50 parts of water. Brown amorphous precipitates, some becoming crystalline, insoluble in hydrochloric acid.

Dragendorff's reagent. 8 grm. of bismuth subnitrate are dissolved in 20 cc. of nitric acid (Sp. Gr. 1·18), and a concentrated solution of 22·7 grm. of potassium iodide added slowly. The mixture is cooled, and the potassium nitrate which crystallises is separated. The solution of $KBiI_4$ obtained gives orange amorphous precipitates with solutions acidified with sulphuric acid.

Erdmann's reagent. 10 drops of dilute nitric acid in 20 cc. of concentrated sulphuric acid.

Fröhde's reagent. 1 grm. of ammonium molybdate in 10 cc. of concentrated sulphuric acid.

Mandelin's reagent (sulpho-vanadic acid). One per cent. solution of sodium vanadate in conc. sulphuric acid.

Marmé's reagent. 10 grm. of cadmium iodide are dissolved in 60 cc. of a warm solution containing 20 grm. of potassium iodide, and an equal volume of a cold saturated solution of potassium iodide added.

Mayer's reagent. 13·55 grm. of mercuric chloride and 50 grm. potassium iodide in a litre of water. Amorphous

or crystalline precipitates with most alkaloids in slightly acid solution; amorphous precipitates with nicotine and coniine becomes crystalline on standing 24 hours. No precipitate with xanthine or xanthine derivatives.

Sonnenschein's reagent (phosphomolybdic acid). Ammonium phosphomolybdate is prepared by addition of sodium phosphate to the usual ammonium molybdate solution. The precipitate is washed and dissolved in 10 per cent. sodium carbonate solution, the solution evaporated to dryness, and the residue ignited after moistening with nitric acid. The residue is dissolved in 30 per cent. nitric acid to give a 10 per cent. solution. Gives yellow to brown precipitates, insoluble in dilute acids, but soluble in concentrated hydrochloric and warm nitric acids. Alkaloid may be obtained from ppt. by warming with barium carbonate and extracting with alcohol.

Scheibler's reagent. Sodium tungstate is digested with half its weight of phosphoric acid (Sp. Gr. 1·13) and allowed to stand for some days until crystals of phosphotungstic acid separate. A solution of the crystals gives a precipitate with most alkaloids.

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Colour Reactions of Alkaloids.

Alkaloid	Conc. H_2SO_4	HNO_3 (Sp. Gr. 1·40)	Erdmann's reagent	Fröhde's reagent
Aconitine	Pale yellow	No colrn.	Pale yellow	Pale yellow
Atropine	No colrn.	No colrn.	No colrn.	No colrn.
Berberine	Olive-green	Reddish-brown	Olive-green	Brownish-green
Brucine	No colrn.	Blood-red	Red	Red
Caffeine	No colrn.	No colrn.	No colrn.	No colrn.
Cinchonine	No colrn.	No colrn.	No colrn.	No colrn.
Cocaine	No colrn.	No colrn.	No colrn.	No colrn.
Codeine	Cold, no colrn.; warm, violet	Yellow	Yellowish-brown to dull green	Green to blue.
Colchicine	Yellow	Violet to brownish-yellow	Yellow	yellow
Coniine	No colrn.	No colrn.	No colrn.	Slowly yellow
Curarine	Red	Purple	Violet	Violet
Delphinine	Brown	Yellowish	Brownish	Red-brown
Emetine	Pale brown	Yellow	Yellow	Pale brown
Morphine	No colrn.	Yellowish-red	Brownish-red to brown	Violet to green brownish-yellow
Narceine	Yellow to brownish-yellow	Yellow, temporary	Brown to violet to dirty red	Yellowish-brown
Narcotine	Pale yellow to yellowish red	Yellow to colourless	Red	Blue-green to green, then red-yellow
Nicotine	No colrn.	No colrn.	No colrn.	No colrn.
Papaverine	Violet-blue	Yellow to orange	Dirty violet to blue-green	Violet-blue to yellow
Quinine	No colrn.	No colrn.	No colrn.	No colrn.
Strychnine	No colrn.	Yellow	No colrn.	No colrn.
Thebaine	Blood-red to yellowish-red	Yellow	Blood-red to yellowish-red	Red to reddish-yellow
Veratrine	Orange to blood-red	Yellow	Orange to blood-red	Yellow to red

Delicacy of Certain Precipitating Agents.

1 part alkaloid in parts solution.	$KHgI_3$	KI_3	Picric acid.	Phospho-molybdic.
Atropine	4,000	8,000	450	4,000
Brucine	30,000	40,000	—	5,000
Cinchonine	50,000	50,000	50,000	50,000
Codeine	30,000	30,000	—	30,000
Colchicine	—	2,500	—	3,300
Coniine	800	10,000	—	1,000
Morphine	1,000 (copious ppt.)	5,000	(no ppt.)	1,000 (distinct ppt.)
Strychnine	8,000	80,000	20,000	14,000
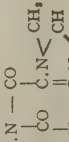
Characteristics of the Alkaloids.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Acetomorphine (syn. diamorphine) from morphine	$C_{17}H_{17}NO_3(C_2H_3O_2)_2$ diacetylmorphine	M.P. 171°	aq 0·11 alc. 2·5 sol. in acids	HNO_3 produces a yellow colour; on warning becomes greenish blue and finally yellow. Alc. and H_2SO_4 on warming give odour of ethyl acetate.
Acetomorphine hydrochloride	$C_{19}H_{18}ONCH_3(O.COCH_3)_2$, HCl	M.P. 231°	aq 33 alc. 9 insol.in ether	
Aconitine *Aconitum napus* (monkshood) and other *aconitum* species	$C_{31}H_{27}(OCH_3)_4.NO < {\stackrel{COCH_3}{COC_6H_5}}$ acetyl benzoyl aconine	M.P. 204—205°	aq 0·02 alc. 22 ether 50 C_6H_6 s. sol.	Conc. H_2SO_4 and HNO_3 dissolve to colourless solns. Sol. in H_3PO_4 gives no coloration on evaporation. Salts laevorotatory. Dextrorotatory. Exceedingly poisonous.
Adenine Pancreas, tea and yeast.	$N = C.NH_2$ $HC \genfrac{}{}{0pt}{}{\parallel}{\parallel} \genfrac{}{}{0pt}{}{C-NH}{C-N} \genfrac{}{}{0pt}{}{}{} CH +3H_2O$ 6-aminopurine	loses aq 110° sublimes 220° decomp. 250°	aq 0·09 insol. ether and $CHCl_3$ s. sol. alc.	Sol. in dil. ammonia; no ppt. with lead acetate. Neutral reaction.
Adrenine (syn. adrenalin) suprarenal gland and synthetic	$HO > C_6H_4 - C{\stackrel{OH}{\underset{H}{|}}}.CH_2.NH.CH_3$ dihydroxy phenyl ethanol methylamine	decomp. 207°		With ferric chloride, emerald green soln. which with very dil. NaOH becomes purple then carmine. Gold and silver salts reduced. Fehling's soln. reduced on boiling. Soln. in NaOH has odour resembling phosphine.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Alstonine *Alstonia constricta*	$2 C_{21}H_{20}N_2O_4 + 7 H_2O$	M.P. 100° anhydr. M.P. 195° M.P. 175°	readily sol. in acids	
Amylocaine hydrochloride (synthetic)	$CH_3 > C < {}^{O.CO.C_6H_5}_{CH_2.N(CH_3)_2.HCl}$ dimethyl amino benzoyl dimethyl ethyl carbinol		aq 7	Local anæsthetic.
Anagyrine *Anagyris fœtida*	$C_{15}H_{22}N_2O$ butyl cytisine (?		Sol. in aq, alc, and ether	Lævorotatory. Aurichloride M.P. 210°.
Anhaline *Anhalonium* species *Cactaceæ*	$C_{10}H_{17}NO$	M.P. 115°	s. sol. aq sol. in alc., ether, and $CHCl_3$	Soln. in conc. H_2SO_4 colourless, green on addition of HNO_3. Yellow soln. in HNO_3 becomes orange on addition of KOH. Not mydriatic.
Apoatropine from atropine	See atropine $........CH.O.CO.C:CH_2$ $\qquad\qquad\dot{C}_6H_5$	M.P. 60°	s. sol. aq sol. alc., amyl alc., and C_6H_6	
Apocinchonine from cinchonine	$C_{19}H_{20}NO$	M.P. 209°	Sol. in aq, alc. and in alkalies	Ethyl ester M.P. 70°. Acetyl ester M.P. 118°
Apocodeine from codeine	$C_{18}H_{19}NO_2$			Dragendorff's reagent brown ppt. Meyer's reagent dull buff ppt. Hypodermic purgative.
Apocodeine hydrochloride	$C_{18}H_{19}NO_2,HCl$	decomp. 200°	v. sol. aq sol. alc.	
Apomorphine from morphine	$C_{17}H_{17}NO_2$	M.P.295°—300°	s. sol. aq r. sol. alc., ether, and $CHCl_3$	White, becoming green on exposure to light and air. Conc. HNO_3: dull red soln. Fröhde's reagent green. Hypodermic emetic.
Apomorphine hydrochloride	$C_{17}H_{17}NO_2,HCl(+H_2O?$	M.P. 270°	aq 1·6 alc. 2	
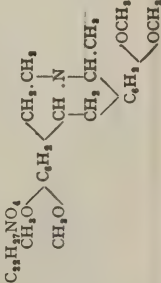
Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Apoquinine from quinine	$C_{19}H_{22}N_2O_2$ substitution of OCH_3 in quinine by OH	M.P. 210°	sol. in aq, alc., ether, and NaOH	Soln. not fluorescent. Ethyl ester M.P. 128°. Non-poisonous.
Arecaïdine *Area catechu* (area or betel nuts)	$C_7H_{11}NO_2, H_2O$ $CH_3CH = C.COOH$ $\big\lfloor$ $CH_2.N(CH_3).CH_2$ N—methyl tetrahydronicotinic acid	Anhydrous at 100° M.P. 224°	sol. in aq insol. in alc, ether, $CHCl_3$, and C_6H_6	Aurichloride M.P. 197°.
Arecaïne *Area catechu*	$C_7H_{11}NO_2, H_2O$ $CO.CH(CH_3).CH_2$ $CO_2.N$——NCH_3	Anhydrous at 100° M.P. 213°	sol. in aq insol. in alc, ether, $CHCl_3$, and C_6H_6	Dragendorff's reagent red ppt. Aurichloride M.P. 186°.
Arecoline *Area catechu*	$C_8H_{13}NO_2$ CH_2 ester of arecaïdine $CH_3CH = COOCH_3$ $\big\lfloor$ $CH_2.N(CH_3).CH_2$	oily liquid B.P. 202°	r. sol. aq, alc, ether, and $CHCl_3$	Alkaline reaction. Dragendorff's reagent granular red ppt. Phosphomolybdic acid; white ppt. Myotic, very poisonous. Anthelmintic.
Arginine Lupine and pumpkin seed embryos Albumen	$C_6H_{14}N_4O_2$ $NH:C{<}^{NH_2}_{NH.CH_2.CH_2.CH_2.CH}{<}^{NH_2}_{COOH}$		Sol. in aq	
Aricine *Cinchona pubescens* (Cuscobark)	$C_{23}H_{26}N_2O_4$	M.P. 188°	nsol. in aq	Lavorotatory. Acetate very soluble.
Aspidiospermine *Quebracho blanco*	$C_{22}H_{30}N_2O$	M.P. 205°	aq 0·016 alc. 2·09 sol. in ether, $CHCl_3$, and C_6H_6	Perchloric acid gives red colour. Lavorotatory.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Aspidosamine Quebracho blanco	$C_{22}H_{28}N_2O$	M.P. abt. 100°	Insol. in aq sol. in ether, alc, and CHCl₃ aq 0·2,	Conc. H_2SO_4 forms blue solution, H_2ClO_4 red. Fröhde's reagent blue.
Atropine Atropa belladonna (deadly nightshade) Scopola carniolica Datura stramonium (thorn apple)	$C_{17}H_{23}NO_3$ CH₂.CH——CH.⎫ ⎪N.CH₃ CH.O.CO.CH.CH₂OH CH₂.CH——CH.⎭ C₆H₅	M.P. 115° sublimes	ether and alc, 40, C₆H₆ 3, CHCl₃ 30	Moistened with fuming HNO₃ and evaporated to dryness, the residue with alc. KOH gives a violet colour becoming red. Aurichloride at first oily then crystalline, M.P. 136°. Powerful mydriatic. Optically inactive.
Atropine sulphate	$(C_{17}H_{23}NO_3)_2.H_2SO_4$	M.P. 196°	aq 200, alc. 24, insol. in ether and CHCl₃	Colourless and amorphous. Hydrochloride M.P. 260°. Febrifuge.
Beberine (syn. beberine, pelosine), Nectandra rodiæi (Greenheart)	$C_{18}H_{21}NO_2$	M.P. 214°	aq 100, s. sol. alk. sol. in alc, ether, and NH₃	Amorphous.
Beberine sulphate	Mixture of alkaloid sulphates from green-heart bark.			
Berberine Berberis vulgaris Hydrastis canadensis (Golden seal)	$CH_2{<}{}^O_O{>}C_6H_2{<}{}^{CH_2—CH_2}_{C}{>}N{...}$ ‖=C{<}{}^{..}_{CH}{>} C₆H₂(OCH₃)₂,	M.P. 145° decomp. 150°	aq 0·2, h. aq-v. sol. sol. in a c. sol. in ether	Yellow, crystalline. Hydrochloride sol. in aq 1 in 400. Salts are yellow. Optically inactive.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Brucine $Strychnos$ nux $vomica$ $Strychnos$ $Ignatii$	$C_{23}H_{26}N_2O_4$, $4 H_2O$ $[C_{20}H_{19}(OCH_3)_2O] \underset{N}{\overset{N}{\vert\vert}} CO$ strychnine $+ (CH_2O)_2$	Loses 4 H_2O at 100° M.P. 178°	aq 0·32 alc. v. sol. ether s. sol. $CHCl_3$ 56·7	Soln. in H_2SO_4 is colourless, blood red on addition of trace of HNO_3. Conc. HNO_3 red, yellow on warming, violet on addition of $SnCl_2$. With Na ethylate forms brucic acid. Lavorotatory. Said to be $\frac{1}{40}$ as toxic as strychnine.
Cephaëline $Psychotria$ $Ipecacuanha$	$C_{28}H_{37} \begin{cases} (OCH_3)_3 \\ OH \\ :NH \\ :N \end{cases}$	M.P. 102° Cryst. from ether M.P. 96°–98°	Sol. in alc., $CHCl_3$, C_6H_6, and s. sol. in ether	Emetic. Lavorotatory $[\alpha]_D = -18°$.
Caffeine (syn. theine) $Coffea$ $arabica$ (coffee $\frac{1}{2}$—2%) $Camelia$ $thea$ (tea 2%) $Sterculia$ $acuminata$ (kola 2%) $Paullinia$ $cupana$ (guarana 5%)	$C_8H_{10}N_4O_2$, H_2O $H_3C.N - CO$ $\vert\quad\quad CO \; C.N<^{CH_3}_{}$ $\vert\quad\quad \vert\vert\quad CH$ $H_3C.N - C.N$ 1.3.7–trimethylxanthine	Anhydr. 100° M.P. 230·5° Sublimes 237° B.P. 384° decomp.	aq 1·25 B, aq 50 alc. 2 ether 0·185	Moistened with strong HNO_3 or dissolved in Cl water and evaporated leaves an orange residue turned purple by NH_3 (soln. or gas), discharged by KOH. Not pptd. by Mayer's reagent. Caffeine citrate is an unstable salt hydrolysed by water.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Cevadine (syn. veratrine) *Schoenocaulon officinale* (sabadilla seed)	$C_{32}H_{49}NO_9$, $2\ C_2H_5OH$, $C_{27}H_{41}NO_8(OH).CO.C_4H_7$	M.P. 205° (alc. free)	Insol. in aq sol. in alc. and ether	Soln. in warm conc. H_2SO_4 is blood red. H_2SO_4 with sugar gives green colour becoming blue. Aurichloride M.P. 182°. Optically inactive. Hydrolysed decomp. into cevine and tiglic acid ($C_4H_7.COOH$). The mixture of alkaloids from sabadilla is also called Veratrine (M.P. 150°)
Cevine (syn. cevadine) by hydrolysis of cevadine	$C_{27}H_{41}NO_6(OH)_2$	M.P. 195—200°	insol. in alc. and ether sol. in acids	Amorphous. Hydrochloride M.P. 240°.
Chelidonine *Chelidonium majus*	$C_{20}H_{19}NO$	M.P. 130°	Insol. in aq r. sol. in alc. and ether	With guaiacum tincture and H_2SO_4 gives a carmine colour. Aurichloride forms purple needles.
Cinchonine *Cinchona* species	$C_{19}H_{22}N_2O$ quinine without CH_3O.group	sublimes 220° M.P. 255°	aq 0·027 alc. 0·7 ether 0·3 $CHCl_3$ 4·3	Dibasic. Not fluorescent. Dextrorotatory. Alc. soln. $[α]_D = +223·3$. Sulphate sol. in aq 1 in 100. M.P. 205°
Cinchonidine *Cinchona* species	$C_{19}H_{22}N_2O$	M.P. 202°	s. sol. aq alc. 6	Laevorotatory. Not fluorescent. Hydrochloride sol. 1 in 20 aq.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Cocaine *Erythroxylon coca* (coca leaves)	$C_{17}H_{21}NO_4$. $CH_2.CH$——$CH.COOCH_3$ $\mid\quad NCH_3\ \ CH.O.CO.C_6H_5$ $CH_2.CH$——CH_2 benzoyl—methyl—ecgonine	M.P. 98°	aq 0·14 alc. 10 $CHCl_3$, 200 ether 25 C_6H_6, 33	Warmed with H_2SO_4, evolves vapour of benzoic acid. Hydrolysed decomposes into CH_3OH, C_6H_5COOH and ecgonine. Laevorotatory. Local anaesthetic.
Cocaine hydrochloride	$C_{17}H_{21}NO_4$HCl			
Codamine opium (·3 to 2%)	$C_{19}H_{23}NO(OH)(OCH_3)_2$	M.P. 183°	aq 200 alc. 33 $CHCl_3$, 5 sol. in hot aq r. sol. in alc. and ether	Strong base which forms amorphous salts.
Codeine opium (·2 to ·8%) and from morphine	$C_{18}H_{21}NO_3$, H_2O methyl—morphine $C_{17}H_{17}NO(OCH_3)(OH)$	M.P. 155° anhydr.	aq 1·3 boil. aq 5·9 alc. 50 $CHCl_3$, 50 ether 3·3	Conc. H_2SO_4 with $FeCl_3$ gives blue soln. in conc. H_2SO_4 with sugar soln. red colour. Fröhde's reagent gives yellow, green then blue. Laevorotatory.
Codeine phosphate	$C_{17}H_{18}(CH_3)NO_3.H_3PO_4.1\frac{1}{2}H_2O$	Anhydr. at 100° M.P. 235°	aq 28 boil. aq v. sol. alc. 0·5	
Colchicine *Colchicum autumnale* (meadow saffron) seeds and corms	$C_{22}H_{25}NO_6$ $C_{20}H_{23}\left\{\begin{array}{l}CH_3 \\ CO.OCH_3 \\ NH\ COCH_3\end{array}\right.$	M.P. 143°	sol. in aq, alc., and $CHCl_3$, v. slightly sol. in ether	Amorphous. Soln. in H_2SO_4 with HNO_3 greenish blue colour passing through sky blue to yellow then red. HNO_3 produces dull violet colour becoming greenish then yellow. Laevorotatory. Specific for gout.
Colchicine salicylate	$C_{22}H_{25}NO_6.C_6H_4(COO)(OH)$	M.P. 55—60°	sol. in aq alc., and ether	
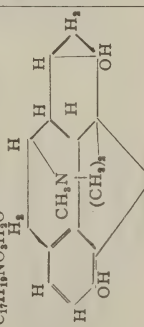
Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Colchicine *Colchicum autumnale*	$2C_{22}H_{25}NO_6 + H_2O$ methyl colchicine	M.P. 148° anhydrous 172°	s. sol. in aq. insol. in ether v. sol. in alc. and $CHCl_3$	Same reactions as colchicine.
Coniine *Conium maculatum* hemlock (syn. cicutine	$C_8H_{17}N$ ... dextro α propyl piperdine	M.P. −2° B.P. 166°	aq. 1 v. sol. in alc, sol. in ether, $CHCl_3$, benzene and acetone	Volatile liquid with mouse-like odour. Alkaline reaction Sp Gr 0·890. Conc. H_2SO_4 gives a blood red colour becoming green. No ppt. with $PtCl_4$; Aurichloride M.P. 77. Dextrorotatory $[\alpha]_D = +15·7$. Intensely poisonous.
Conhydrine *C. maculatum*	$C_8H_{17}NO$ ... $C(OH)CH_2CH_2CH_3$ oxyconiine	M.P. $\{(a)\ 100°$ $(b)\ 91°$ B.P. 224°	s. sol. in alc, ether, and chlf.	Aurichloride M.P. 133°. Dextrorotatory.
Corydaline *Corydalis cava*	$C_{22}H_{27}NO_4$ ...	M.P. 134°	insol. in aq, sol. in alc, ether and $CHCl_3$	Dextrorotatory. Aurichloride M.P. 207°.
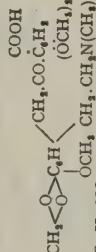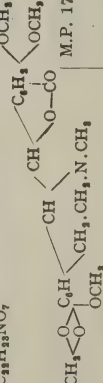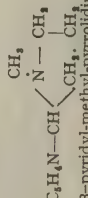
Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Corynine *Corynanthe Yohimbi*	$C_{21}H_{22}N_2O_4$ tertiary base	M.P. 231—234°	v.s. sol. in aq sol. in alc., methyl alc., acetone, and $CHCl_3$. s. sol. in ether	Soln. in H_2SO_4 is colourless. Soln. in HNO_3 is deep green becoming yellow, on addition of KOH (alcoholic) becomes cherry red. Bleaching powder: orange red colour. Dextrorotatory.
Cotarnine oxidation of narcotine	$C_{12}H_{15}NO_4$ OCH₃, COH, CH₂, O, CH₂.CH₂.NH.CH₃	M.P. 132—135°	s. sol. in aq sol. in alc. v. sol. in ether sol. in NH_4OH	Soln. in HNO_3 is red. Oxidised by HNO_3 yields apophyllenic acid $C_6H_3N_2O_4$. Reduced yields hydrocotarnine.
Cotarnine hydrochloride Cotarnine phthalate	$C_{12}H_{14}NO_4HCl$ $(C_{12}H_{14}NO_4)_2$ $C_6H_4(COOH)_2$	M.P. 102—103°	Readily sol. in alc. and aq. Readily sol. in aq	Yellow crystals. Styptic. Styptic.
Cormitine	See ergotoxine			
Cupreine *Remijia pedunculata* and *Cinchona* species	$C_{15}H_{19}N_3O_2$, 2 H_2O oxycinchonine	anhydrous at 120 —125°, of wh. M.P. 198°	s. sol. in aq, ether, $CHCl_3$, sol. in alc. and in alkalies.	Alcoholic soln. with Fe_2Cl_6, reddish brown; with Cl, then NH_3; dull green. Lævorotatory. Not fluorescent.
Curarine from Curare an extract of *Strychnos toxifera* and other species (arrow poison)	$C_{19}H_{35}N_2O$		sol. in aq and alc.	Conc. H_2SO_4 gives red; H_2SO_4 with $K_2Cr_2O_7$, gives blue, becoming violet then red. Intensely poisonous when injected hypodermically, almost inert taken orally. Amorphous.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Curine N.B.—Source same as above	$C_{18}H_{19}NO_3$	M.P. 212° Cryst. from alc. M.P. 160°	s. sol. in aq sol. in abs. alc. C_6H_6 and $CHCl_3$	With Mandelin's reagent, white then bright red. Laevorotatory.
Cusconine *Cinchona* species	$C_{23}H_{26}N_2O_4$, 2 H_2O	anhydr. at 100° M.P. 110°	insol. in aq sol. in alc. and ether	Laevorotatory.
Cusparine *Cusparia febrifuga* (Angostura bark)	$C_{20}H_{19}NO_3$	M.P. 89°	Sol. in alc., ether, $CHCl_3$, acetone, and C_6H_6	Soln. in conc. H_2SO_4 is cherry red; in HNO_3 is yellow. Fröhde's reagent, deep blue. Aurichloride M.P. 190°
Cystisine *Cystisus laburnum* (laburnum)	$C_{11}H_{14}N_2O$ dibasic, containing one NH group	M.P. 152° sublimes	r. sol. in aq, alc., C_6H_6, and $CHCl_3$; insol. in CCl_4 sol. in ether and acetone	Dragendorff's reagent dull red deposit; Fe_2Cl_6 gives a blood red soln, becoming colourless then blue on addition of H_2O_2. Alkaline reaction.
Delphinine *Delphinium staphisagria* (stavesacre)	$C_{31}H_{49}NO_7$	decomp. 120°	sol. in abs, alc., ether 9 ; $CHCl_3$ 6·25 s. sol. in aq	Optically inactive.
Diamorphine	See acetomorphine			
Ditamine *Alstonia (Echites) scholaris*	$C_{16}H_{19}NO_2$	M.P. 75°	insol. in aq sol. in ether, $CHCl_3$ and acids	Conc. HNO_3 forms yellow soln., which on warming becomes green then orange red.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Duboisine *Duboisia myoporoides*	Mixture of hyoscyamine and hyoscine			Mydriatic.
Ecgonine (hydrolysis of cocaine)	$C_9H_{15}NO_3$ H_2O CH₂.CH — CH.COOH | NCH₃ | CH₂.CH — CH₂ tropine carboxylic acid	M.P. 205° anhydrous	sol. in aq s. sol. in alc sol. in ether	Laevorotatory. Platinichloride, orange M.P. 226°
Echitamine *Alstonia (Echites scholaris)*	$C_{22}H_{28}N_2O_4$ H_2O monobasic	M.P. 105° anhydrous 206° decomp.	sol. in aq, alc, acetone.	Soln. in conc. H_2SO_4 is red, on addition of HNO_3 becoming green.
Echitenine source same as above	$C_{20}H_{27}NO_4$	M.P. 120°	insol. in C_6H_6, sol. in alc. and $CHCl_3$.	Laevoro tory. Strongly basic. Soln. in conc. H_2SO_4 is violet red: in HNO_3, red, then green, finally yellow. Forms amorphous salts.
Emetine *P sychotria ipecacuanha*	$C_{28}H_{40}N_2O_4$ $\left\{\begin{array}{l}O(CH_2)_4 \\ :NH \\ ::N\end{array}\right.$ $C_{27}H_{37}$ O. methyl ester of cephaeline.	M.P. 68°	s. sol. in aq sol. in alc., $CHCl_3$, ether, C_6H_6, and solns. of alkalies.	Fröhde's reagent brown on addition of conc. HCl deep blue $[\alpha]_D = -22°$ Hydrochloride $[\alpha]_D = +16°$ Much less emetic than cephaline.
Ergotinine *Secale cornutum Claviceps purpurea* a fungus growing ou rye, *secale cereale* (ergot or spurred rye)	$C_{35}H_{40}N_4O_6$ (?) anhydride of ergotoxine	Darkens about 210° M.P. about 229°	insol. in aq alc. 0·5, hot alc. 2, v. sol. in $CHCl_3$, ether 0·1	Ppt. with Meyer's reagent. Soln. in acetic ether with conc. H_2SO_4 gives an orange coloration, changing to violet. Dextrorotatory. Sat. alc. soln. $[\alpha]_D = +335°$. Physiologically almost inactive

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Ergotoxine (syn. cornutine) same as above	$C_{35}H_{41}N_5O_6$	Softens at 155° M.P. 162—164°	insol. in aq sol. in alc s. sol. in ether v. sol. in NaOH	Ppt. with Meyer's reagent. Amorphous. HCl sol. in aq 1 in 6,000. Strongly active physiologically
Eserine *Physostigma venenosum* (calabar or ordeal bean)	$C_{15}H_{21}N_3O_2$	M.P. 105—106°	s. sol. in aq s. sol. in alc, ether, $CHCl_3$ and CS_2	Dissolves in conc HNO_3, to yellow soln. becoming olive green. Soln. in dil. H_2SO_4 warmed with NH_3, becomes red, yellow, green, then blue. Laevorotatory. Very poisonous. Myotic.
Ethyl morphine hydrochloride	$C_{17}H_{18}NO_3C_2H_5$, HCl, H_2O	M.P. 124°	aq 10 (about) alc. 25 hot alc. 100 insol. in ether and $CHCl_3$	Soln. in H_2SO_4 colourless, violet on addition of $FeCl_3$, deep red on further addition of HNO_3.
Gelsemine *Gelsemium nitidum* (yellow jasmine)	$C_{22}H_{26}N_2O_4$ contains one OH group	M.P. 160°	sol. in alc., ether, and C_6H_6	Conc HNO_3, on warming gives a reddish coloration, then dull green. Crystalline.
Guvacin *Areca catechu* (areca nuts)	$C_6H_9NO_2$ CO.CH(CH_2). CH_2 | | CO.CH₂ —— NH	M.P. 272° decomp.	sol. in aq ; insol. in alc., ether and $CHCl_3$	Aurichloride M.P. 194—195°.
Homatropine from tropine	$C_{17}H_{21}NO_3$	M.P. 99°	s. sol. in aq sol. in $CHCl_3$	Hydrobromide sol. in aq 1 in 6. M.P. 217°. Mydriatic.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Hydrastine *Hydrastis canadensis* (golden seal)	$C_{21}H_{21}NO_6$ $CH_2<^O_O>C_6H_3<^{CH_2.CH_2}_{CH.N.CH_3}$ $CH.O.CO$ $C_6H_2<(OCH_3)_3$	M.P. 133°	insol. in aq sol. in alc. and in ether s. sol. in C_6H_6 and in $CHCl_3$	Fröhde's reagent olive green. Mandelin's reagent red, then orange. Lævorotatory in neutral soln. Dextrorotatory in acid soln.
Hydrastinine from hydrastine by oxidation.	$C_{11}H_{11}NO_3$ $CH_2<^O_O>C_6H_2<^{CH_2.CH_2.NH}_{CHO}>CH_3$	M.P. 116–117°	insol. in aq sol. in hot aq, s. sol. in alc., ether and $CHCl_3$	Ppt. by KOH, not ppt. by NH_3 or Na_2CO_3, Nessler's soln. reduced, black ppt. of Hg formed. HCl salt M.P. 210° v. sol in aq. Raises blood pressure.
Hydroquinine *Cinchona* species	$C_{20}H_{24}N_2O_2$	M.P. 168°	s. sol. aq scl. in alc. and $CHCl_3$	Dextrorotatory and fluorescent. Cl then NH_3 gives green.
Hygrine *Erythroxylum coca*	$C_8H_{14}NO$ $CH_2.CH.CO.C_2H_5$ CH_2 CH_2 $N.CH_3$	B.P. 193–195°, 93° at 20 mm.	sol. in ether	Picrate M.P. 148° $[\alpha]_D = -1.3°$. Sp. Gr. 0·935.
Hyoscine (syn. scopolamine) *Datura alba* *Hyoscyamus niger*	$C_{17}H_{21}NO_4$	M.P. 59°	sol. in aq s. sol. in alc., ether, and $CHCl_3$	H_2SO_4 gives no colour. Moistened with HNO_3, and evaporated, residue with alc. KOH is coloured violet. Hydrobromide M.P. 193°, sol. in aq 1 in 4. Aurichloride M.P. 199° Lævorotatory. Mydriatic.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Hyoscyamine *Hyoscyamine niger* (henbane)	$C_{17}H_{23}NO_3$ isomeric with atropine	M.P. 108·5°	sol. in aq, alc. and $CHCl_3$	Lævorotatory $[\alpha]_D = -21°$. Sulphate M.P. 200°. Aurichloride M.P. 162°.
Jervine *Veratrum album* (white hellebore)	$C_{26}H_{37}NO_3$	M.P. 238—242°	sol. in alc, $CHCl_3$, acetone s. sol. in ether insol. in C_6H_6 s. sol. in ether $CHCl_3$	Conc. H_2SO_4 gives a yellow then dull green.
Laudanine Opium	$C_{20}H_{25}NO_4$	M.P. 166°	s. sol. in alc. $CHCl_3$, s. sol. in ether	Optically inactive. Soln. in H_2SO_4 rose coloured changing to violet on warming
Lupinine *Lupinus luteus* Lupinidine Meroquinene *Cinchona* species and from cinchonine	$C_{15}H_{16}N_2O_2$ dibasic having 2 OH groups $C_{15}H_{16}N_2$ $C_9H_{16}NO_2$ $NH\begin{cases} CH_2 - CH_3 \\ CH_2 - CH - \end{cases} \begin{matrix} .CH.CH.COOH \\ CH_2CH_3 \end{matrix}$ β vinyl piperidine acetic acid	M.P. 67° B.P. 256° B.P. 311—314° M.P. 222°	s. sol. b. aq sol. in aq	Lævorotatory. Aurichloride M.P. 189°. $C_5H_4N(COOH)CH_2.COOH$ meroquinene. $C_5H_4N(COOH)CH_2.COOH$ cincholoiponic acid $C_5H_4N(COOH).COOH$ loiponic acid.
Morphine Opium (3 to 23%) the dried latex of *Papaver somniferum* (white poppy)	$C_{17}H_{19}NO_3.H_2O$	anhydr. at 120° M.P. 230° decomp.	aq 0·01 B. aq 0·25 hot alc. 7·5 insol. in ether v.s. sol. in $CHCl_3$, and C_6H_6	Dissolves in H_2SO_4 to colourless soln., on addition of Fe_2Cl_6 becomes crimson. Soln. of morphine salts liberate iodine from HIO_3. Neut. Fe_2Cl_6 gives blue colour discharged by acids or warming; $K_3FeC_6N_6$ with Fe_2Cl_6 (neut.) give blue soln., then blue ppt. Heated to 140—190° with HCl forms apomorphine $C_{17}H_{17}NO_2$.
Morphine acetate	Tetrahydro-phenanthrene deriv. $C_{17}H_{19}NO_3, C_2H_4O_2$	M.P. 200° decom.	aq 40	[*See over*

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Morphine hydrochloride	$C_{17}H_{19}NO_3,HCl, 3 H_2O$	loses 3 H_2O 100° decomp. 250°	aq 4·17 boil. aq 100 alc. 2	(contd.): Fröhde's reagentet, viol blue, then green. Laevorotatory. Distilled with zinc dust yields phenandrene.
Morphine sulphate	$(C_{17}H_{19}NO_3)_2,H_2SO_4, 5 H_2O$	anhyd. 100° decomp. 250°	aq 4·5 alc. 0·14 insol. in $CHCl_3$	
Morphine tartrate Narceine opium (0·1—0·2%)	$(C_{17}H_{19}NO_3)_2(CHOHCOOH)_2, 3 H_2O$ $C_{23}H_{27}NO_8, 3 H_2O$	anhydr. at 130° M.P. 145° anhydr. 170°	aq 10 aq 0·1 hot aq 0·4 alc. 0·1	Dilute iodine soln. gives blue colour. Fröhde's reagent green then blood red. Optically inactive. Strongly narcotic.
Narcotine opium (2—10%)	$C_{22}H_{23}NO_7$	M.P. 176°	aq 0·08 hot aq 0·15 alc. 1 ether 1 $CHCl_3$ 34	Conc. H_2SO_4, then HNO_3 red. Fröhde's reagent green, yellow then colourless. Laevorotatory in neut. solns. Dextrorotatory in acid soln. Narcotine $+ H_2O + O =$ cotarnine + opianic acid.
Nicotine Nicotiana tabacum (0·6 to 8%) (tobacco) N. glutinosa, N. rustica	$C_{10}H_{14}N_2$ β-pyridyl-methyl-pyrrolidine	B.P. 247°	sol. in aq, alc, and ether	Sp. Gr. 1·01. Conc. H_2SO_4, and conc. HNO_3 produce no colour. Cl water red to brown colour. Oxidised and distilled with CaO yields pyridine. Laevorotatory[α]ᴅ = −161·55° Salts are dextrorotatory.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Papaverine Opium (1%)	$C_{20}H_{21}NO_4$ $CH_3O>C_{19}H_9N.CH_2.C_6H_3<^{OCH_3}_{OCH_3}$ isoquinoline deriv. $C_9H_{11}NO$	M.P. 147°	insol. in aq sol. in alc. and in ether	With warm H_2SO_4, violet. Fröhde's reagent violet then cherry red.
Pelletierine (syn. punicine) *Punica granatum* (pomegranate root bark)	$C_9H_{11}NO$	B.P. 195° partly decomp. B.P. 125° at 100 mm.	aq 4·3 sol. in alc. and $CHCl_3$	Sp. Gr. ·988. Ppt. by $AuCl_3$, tannin, Sonnenschein's reagent, and Bouchardat's reagent. No ppt. with $PtCl_4$. Lævorotatory $[α]_D = -30°$. Inactive at 100°. Salts dextrorotatory. Anthelmintic.
Pelletierine tannate		decomp.	aq 0·014 alc. 1·25	
Physostigmine	See Eserine			
Pilocarpine *Pilocarpus jaborandi* *P. macrophyllus*	$C_{11}H_{16}N_2O_2$ $C_2H_5.CH-CH.CH_2.CH_2.C-N-CH_3$ $\quad\quad\quad |\quad\quad\quad :CH.N\rangle CH$ $\quad CO.OCH_3$	B.P. 261° at 10 mm.	sol. in aq, alc., and $CHCl_3$	Syrupy liquid. $[α]_D = +100·5°$. Picrate, sol. in alc. M.P. 160°. Ppt by $Au Cl_3$. H_2SO_4 with $K_2Cr_2O_7$ fives grass green colour. Heated to 180° forms pilocarpidin
Pilocarpine hydrochloride	$C_{11}H_{16}N_2O_2$, HCl	M.P. 204—205°	v. sol. in aq alc. 10	$[α]_D +90°$ to 92°.
Pilocarpine nitrate	$C_{11}H_{16}N_2O_2$, HNO_3	M.P. 176°	aq 12·5 alc. 2 sol. in aq and alc.	$[α]_D$ above $+80°$.
Pilocarpidine same as above	$C_{10}H_{14}N_2O_2$ $C_2H_4N.C(CH_3).N(CH')$ $\quad\quad\quad\quad COOH$		sol. in aq and alc.	Syrupy liquid. HCl soln. $[α]_D = +72°$. Aurichloride M.P. 120—121°.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions
Piperine *Piper nigrum* (black pepper) 8%	$C_{17}H_{19}NO_3$, $CH_2<^{CH_2.CH_2}_{CH_2.CH_2}>N.CO.CH=$ $CH_=<^O_O>C_6H_3.CH:CH.CH$ Piperidine+piperic acid$-H_2O$	M.P. 130°	almost insol. in aq sol. in alc. B. alc. 100 ether and $CHCl_3$.	Soln. in H_2SO_4 is blood red, colourless on addition of water. H_2SO_4 with HCHO gives permanent green colour. Optically inactive.
Pseudoaconitine *Aconitum ferox* (napaul aconite)	$C_{36}H_{49}NO_{12}$, $C_{21}H_{28}(OCH_3)_4NO_2<^{O.CO.CH_3}_{O.CO.C_6H_3.(OCH_3)_2}$	M.P. 210—212°	v.s. sol. in alc. and $CHCl_3$	Aurichloride M.P. 237°. Intensely poisonous.
Pseudopelletierine *Punica granatum*	$C_9H_{15}NO$ $CH_2.CH \!-\! CH_2$ $\quad | \qquad\qquad\; CO$ $CH_2.N.CH_3$ $\quad | \qquad\qquad\; CH_2$ $CH_2.CH \!-\! CH_2$	M.P. 48° B.P. 246°	sol. in alc., ether and $CHCl_3$	$K_2Cr_2O_7 + H_2SO_4$ gives green colour. Ppt. by tannin, phosphomolybdic acid, and Meyer's soln. Optically inactive.
Quinine *Cinchona succirubra* (red cinchona or Peruvian bark) about 3% *Cinchona calisaya* (yellow cinchona) *Cinchona ledgeriana* *Cinchona officinalis* and other *Cinchona* species *Remijia pedunculata* and other species	$C_{20}H_{24}N_2O_2$, $3\ H_2O$ $\quad\quad CH_2 \!-\! CH_2$ $\quad OH\ N \qquad |\quad CH_2$ $\qquad | \qquad\quad | \;\; H_2C \quad CH$ $CH_2 \!-\! C\ CH_2 \qquad \!\!-\! C \!=\!$ $\qquad\qquad | \qquad\quad H \quad CH_2$ $CH_3O \!-\! C_6H_4N \qquad\qquad CH$	fuses 57° anhydr. at 125° anhydr. M.P. 174°	aq 0·051 alc. 100 ether 25 $CHCl_3$ 33 sol. in dil. acids, NH_3 and C_6H_6	Soln. with Cl (or Br) water and NH_3 gives green colour (thalleioquin) changing to red on addition of acid. Soln. in conc. H_2SO_4 colourless. Colourless solns. have blue fluorescence. Lævorotatory.
Quinidine	$2C_{20}H_{24}N_2O_2$, $5\ H_2O$	M.P. 171·5 anhydr.	s. sol. in aq. sol. in alc. and ether.	Cl and NH_3 same as quinine. Soln. in alc. and H_2SO_4 has blue fluorescence. Dextrorotatory.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Quinine acetyl salicylate	$C_{20}H_{24}N_2O_2 . C_6H_4 . COOH . O . COCH_3$	M.P. 157°	aq 0·03 alc. 2	Almost tasteless.
Quinine ethyl carbonate	$C_{20}H_{23}N_2OC_2H_5CO_3$	M.P. 95°	CHCl₃ 14 s. sol. aq r. sol. alc.	
Quinine hydrobromide	$C_{20}H_{24}N_2O_2HBr, H_2O$	anhydr. at 100° melts 150—200°	aq 1·8 B. aq 100 alc. 143	
Quinine hydrochloride	$C_{20}H_{24}N_2O_2HCl, 2 H_2O$	anhydr. at 130° M.P. 196°	aq 2·5 B. aq 100 alc. 100	Soln. not fluorescent
Quinine acid hydrochloride	$C_{20}H_{24}N_2O_2, 2 HCl, 3 H_2O$		aq 133 alc. 20	
Quinine salicylate	$(C_{20}H_{24}N_2O_2HC_7H_5O_3)_2 H_2O$	anhydr. at 100° M.P. 183—187° decomp.	v.s. sol. in aq alc. 24	Solns. fluorescent.
Quinine acid sulphate	$C_{20}H_{24}N_2O_2 H_2SO_4, 7 H_2O$	M.P. 160° decomp.	alc. 2·2 aq 0·125	Lævorotatory, 5% soln. in 200 mm. tube — 22°
Quinine sulphate	$[(C_{20}H_{24}N_2O_2)_2H_2SO_4], 15 H_2O$	anhydr. at 100° M.P. 205°	B. aq 4 alc. in dil. acids	Antipyretic. Specific in malaria and ague.
Scopolamine	See hyoscine			
Solanine *Solanum* species	$2C_{23}H_{38}NO_{15}, H_2O$ $C_{52}H_{92}NO_{18} = 2 C_6H_{12}O_6 + 4 H_2O + C_{40}H_{61}NO_2$ solanidin	M.P. 244°	sol. in 85% alc. s. sol. in abs. alc., ether insol. in C_6H_6 and CH_2Cl_2	Dissolves in conc. H_2SO_4 to rose coloured soln. With H_2SO_4 and ammon. vanadate yields a brown colour changing to red colour. less on addition of water.
Solaneine same as above	$C_{52}H_{93}NO_{18}$	M.P. 208	sol. in 85% alc.	With H_2SO_4 and ammon. vanadate yields red colour.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Sparteine *Cytisus scoparius* (broom)	$C_{15}H_{26}N_2$ pyridine derivative identical with lupinidine (?)	B.P. 311° under 723 m.m.; 180° under 20 mm.	s. sol. aq viscous liquid. sol. in alc., ether and CHCl₃, insol. in C₆H₆	Alcoholic soln. $[\alpha]_D = -14 \cdot 6°$. Aurichloride yellow.
Stachydrine *Stachys tubifera*	$C_7H_{13}NO_2, H_2O$ $C_3H_7 \cdot NH(CH_2)_3$ (? $\overset{\mid}{CO \cdot O}$	M.P. 100° hydrous.	sol. in alc. and ether	Aurichloride M.P. 190°–210°.
Strychnine *Strychnos nux vomica* (¼ to 1%); *Strychnos ignatia*	$C_{21}H_{22}N_2O_2$	M.P. 265°–266° B.P. 270° under 5 mm.	aq 0·014 boil. aq 0·04 alc. 0·59 abs. alc. 0·3 boil. abs. alc. 2·5 CHCl₃ 16·5 almost insol. in ether	Moistened with H₂SO₄ and K₂Cr₂O₇, produces a violet colour, quickly changing to red then yellow. Conc. HNO₃ yields a yellow soln. Solu. in H₂SO₄ gives with MnCO₂ blue colours, rapidly changes to violet, then rose. Laevorotatory.
Thebaine opium (0·15%)	$C_{19}H_{21}NO_3$ $CH \cdot C_6H_4 \underset{\|}{<}\overset{OCH_3}{\underset{O}{}}CH_2$ $CH \cdot C_6H_4 <\overset{N(CH_3)}{\underset{OCH_3}{}}CH_2$ dihydrophenanthrene deriv.	M.P. 193°	insol. in aq alc. 10 s. sol. in ether, sol. in C₆H₆ and CHCl₃	Dissolves in conc. H₂SO₄ to deep red soln. Fröhde's reagent orange. Laevorotatory. alc. soln. $[\alpha]_D = -218 \cdot 6°$

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Theine (see caffeine) **Theobromine** *Theobroma cacao* (cocoa beans)	$C_7H_8N_4O_2$, H_2O $CH_3.N—CO$ $OC\ C.NCH_3$ $HN—C.N$ $\rangle CH$ 3·7-dimethylxanthine	sublimes 290°	aq (0°) 0·06 aq (100°) 1·82 s. sol. alc. and ether.	Dissolved in Cl water and evaporated leaves brown residue, becoming purple **on** addition of NH_3. Diuretic.
Theophylline *Camellia thea* (tea)	$C_7H_8N_4O_2$, H_2O $CH_3.N—CO$ $OC\ C.NH$ $\rangle CH$ $CH_3.N—C.N$ 1·3-dimethylxanthine	M.P. 130° anhyd. decomp. 218°	sol. in aq. and alc.	Dissolved in Cl water and evaporated leaves red residue, becoming violet on addition of NH_3. Diuretic.
Trigonelline *Trigonellum fænum græcum* (fenugreek seeds)	$C_7H_7NO_2$; H_2O $CO—O$ $CH\ \rangle C\ —CH \rangle N.CH_3$ $CH=CH$ methyl nicotinic betaine	M.P. 218° anhyd.	s. sol. in aq. sol. in alc. insol. in ether and $CHCl_3$	Dragendorff's sohn. gives red ppt.
Tropine from atropine	$C_8H_{15}NO$ $CH_2.CH——CH_2$ $\quad NCH_3\ CHOH$ $CH_2.CH——CH_2$	M.P. 62° B.P. 233°	s. sol. in aq and alc. sol. in ether	Aurichloride M.P. 210°—212° decomposing. Optically inactive. Not mydriatic.

Name and Source.	Formula.	Behaviour on heating.	Parts soluble in 100 parts solvent.	Reactions.
Truxilline β and γ) *Vicia sativa* (vetch) *Trifolium* species	$C_{34}H_{28}N_2O_8$ ester of ecgonine with truxillic acid. (α β or γ) $C_6H_5.CH.CH.CO_2H$ $\quad\|$ $C_6H_5.CH.CH.CO_2H$ α truxillic acid	α M.P. 80° β M.P. 45°	sol. in alc., ether, C_6H_6 and $CHCl_3$ s. sol. in petrol. ether	Amorphous salts amorphous.
Veratrine	See Cevadine.			
Verrine *Vicia sativa* (vetch) *Trifolium* species	$C_{16}H_{20}N_6O_3$, 3 H_2O	anhydr. at 120° M.P. 180° decomp.	insol. in alc. sol. in aq., acids and alkalies. aq 1	Forms guanine when boiled with HCl. Insol. comp. formed with $Hg(NO_3)_2$. Soln. of salts with a trace of Fe_2Cl_6, becomes deep blue.
Vicine *Vicia sativa* (vetch)	$C_{28}H_{31}N_{11}O_{21}$, 2 H_2O	M.P. 122	insol. in abs. alc. sol. in alc. and ether aq 0·007	Dissolves in conc. H_2SO_4, to green soln. becoming violet. Soln. evaporated with Cl water and a trace of HNO_3, leaves a yellow residue, reddened by NH_3 gas. Soln. in dil. HNO_3
Wrightine	$C_{24}H_4N_3$	decomp. 150°	B. aq 0·07 insol. in alc. sol. in acids and alkalies	evaporated, residue just dissolved in KOH and again evaporated leaves blue residue
Xanthine in flesh, urine, tea, etc.	$C_5H_4N_4O_2$ $\text{HN}\!-\!\!-\!\text{CO}$ $\text{OC}\quad\text{C.NH}$ $\text{HN}\!-\!\!-\!\text{C.N}\!\!>\!\!\text{CH}$ 2·6–dioxypurine			
Yohimbine	See Corynine.			
Yohimbenine *Corynanthe yohimbi*	$C_{25}H_{45}N_5O_5$	M.P. 135°	sol. in alc. and $CHCl_3$	Dissolves in conc. H_2SO_4, to light yellow soln.

Pharmaceutical Names of Synthetic Compounds.

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In order to systematise the names the following rules have, as far as possible been adopted :—

Local anæsthetics, if basic, have names ending in *caine*.
Antipyretics have names ending in *in*.
Hypnotics have names ending in *al*.
Antiseptics for external use have names ending in *form*.

Official names are indicated by "B.P." The names in brackets are the proprietary names, or the names under which the drugs were first introduced into medicine.

Acetosalin.	Acetylsalicylic acid (*Aspirin*).
Acetannin.	Diacetyltannin (*Tannigen*).
Acetoxane.	Acetyl-*p*-oxyphenyl urethane (*Neurodin*).
Acriflavine.	See *Flavine*.
Adrenine (*Adrenalin*, B.P.).	*l*-Methylamino ethenol catechol.
Albichthol.	Albumin ichthosulphonate (*Ichthalbin*).
Alphaform.	Bismuth oxyiodogallate (*Airoform*).
Alumnasol.	Aluminium β-naphthol-sulphonate (*Alumnol*).
Amidopyrin.	Dimethylamido-antipyrin (*Pyramidon*).
Amydricaine hydrochloride.	Benzoyl-tetramethyl-diamino-ethyl-dimethyl-carbinol hydrochloride (*Alypin*).
Amylene chloral.	Compound of amylene hydrate and chloral (*Dormiol*).
Amylocaine hydrochloride.	Dimethylamino-benzoyl-dimethylethyl-carbinol hydrochloride (*Stovaine*).
Antifebrin.	Acetanilide.
Antipyrin.	1-Phenyl-2 : 3-dimethyl-pyrazolone.
Argentichthol.	Silver ichthosulphonate (*Ichthargan*).
Argophol.	Silver methylene nucleinate (*Sophol*).
Arsenobenzol.	3 : 3′-Diamino-4 : 4′-dihydroxy-l-arseno-benzene hydrochloride (*Salvarsan*).
Barbitone, B.P.	Diethylbarbituric acid (*Veronal*).
Benzalgen.	8-Ethoxy-5-benzoylaminoquinoline (*Analgen*).

Benzamine, B.P.	Benzoyl-vinyl-diacetone-alkamine (*β-Eucaine*).
Benzocaine.	*p*-Aminobenzoic ethyl ester (*Anæthesine*).
Benzonaphthol.	*β*-Naphthol benzoate.
Benzoxate.	Benzoyl-acetyl-peroxide (*Acetozone*).
Betacaine.	*See* Benzamine.
Betaform.	Bismuth tribromocatechol (*Novoform*).
Bismolinide.	Quinoline bismuth sulphocyanide (*Crurin*).
Bromanilide.	*p*-Bromoacetanilide (*Antisepsin*).
Brombutol.	Tribromo-*tert.*-butyl alcohol (*Brometone*).
Bromobehenate.	Calcium dibromobehenate (*Sabromin*).
Bromophin.	Apomorphine bromo-methylate.
Bromovaletin.	*a*-Bromo-isovaleryl-*p*-phenetidine (*Phenoval*).
Butocresol.	Di-isobutyl-cresol-iodide (*Europhen*).
Cetosalol.	Acetyl-*p*-aminophenol salicylic ester (*Salophen*).
Chloramide, B.P.	Chloral-formamide (*Chloralamide*).
Chloramine T.	Sodium toluene *p*-sulphonchloramide.
Chlorbutol.	Trichloro-*tert.*-butyl alcohol (*Chloretone*).
Chlorpyrin.	Chloral hydrate antipyrin (*Hypnal*).
Citrosalic acid.	Methylene-citryl-salicylic acid (*Novaspirin*).
Cresamol.	Ethylene-diamine tricresol (*Kresamine*).
Cyclocaine.	Isobutyl-*p*-amino-benzoate (*Cycloform*).
Deltaform.	Basic bismuth dithiosalicylate (*Thioform*).
Dimargyl.	Ethylene-diamine silver nitrate or phosphate (*Argentamin*).
Diamorphine, B.P.	Diacetylmorphine (*Heroin*).
Dichloramine T.	*p*.-Toluene sulphon dichloramide.
Dimethylsulphonal.	Diethylsulphone-diethylmethane (*Tetronal*).
Ethocaine *hydrochloride.*	*p*.-Amino-benzoyl-diethylaminoethanol hydrochloride (*Novocaine*).
Eusol.	A solution of hypochlorous acid (0·25—0·3% HClO).
Feminal.	Isoborneol isovalerate (*Gynoval*).
Ferriobenate.	Ferric iodobehenate (*Ferrosajodin*).
Flavine.	Diamino-methyl-acridinium chloride.
Formamine.	Hexamethylenetetramine (*Urotropin*).
Formamol.	Hexamethylenetetramine anhydro-methylene citrate (*Helmitol*).

Formamylum.	Condensation product of formaldehyde and starch (*Amyloform*).
Formichthol.	Formaldehyde ichthosulphonate (*Ichthoform*).
Formotan	Formaldehyde tannin compound (*Tannoform*).
Gammaform.	Bismuth oxy-iodo-dipyrogallate (*Pyroform*).
Gluside, B.P.	Benzoic sulphinide (*Saccharin*).
Glycocaine.	Diethylglycocoll-*p*-amino-*o*-hydroxy-benzoic methyl ester (*Nervanin*).
Glycopyrin.	Antipyrin methyl-ethyl-glycollate (*Astrolin*).
Guaiaglycol.	Guaiacol methyl glycollate (*Monotal*).
Guanicaine hydrochloride.	Di-*p*-anisyl-monophenetyl guanidine hydrochloride (*Acoin*).
Hexamine, B.P.	Hexamethylenetetramine (*Urotropin*).
Iomadrenine hydrochloride.	Amino-ethanol-catechol hydrochloride (*Arterenol hydrochloride*).
Homobarbital.	Dipropyl barbituric acid (*Proponal*).
Hydurol.	Sodium oxymercurisalicylate and amino-oxyisobutyrate (*Asurol*).
Ichthamol.	Ammonium ichthosulphonate (*Ichthyol*)
Iodicyl.	Di-iodo-salicylic methyl ester.
Iodisalin.	Methylene-iododisalicylic acid.
Iovalurea.	Mono-iodo-valeryl urea (*Iodival*)
Malourea, Malonurea.	Diethylbarbituric acid (*Veronal*).
Menthival.	Menthyl valerate + 30% free menthol (*Validol*).
Mercamin.	Ethylenediamine mercury sulphate (*Sublamin*).
Mercotan.	Mercuric cholate with tannin albuminate (*Mergal*).
Mercuritol	Sodium hydroxymercuric toluate (*Afridol*).
Methophan.	8-Methoxy-2-phenylquinoline-4-carboxylic acid.
Methosal.	Methoxy-methyl-salicylate (*Mesotan*).
Methoxetin.	Methoxy-acetyl-*p*-phenetidine (*Kryofine*).
Methylsulphonal, B.P.	Diethylsulphone-dimethyl methane (*Trional*).
Methutin.	Dimethylaminoantipyrin-butyl-chloral-hydrate (*Trigemin*).
Monopyrate.	Pyrogallol monoacetate (*Eugallol*).
Monoresate.	Resorcinol monoacetate (*Euresol*).

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Napthoxytol.	β-Hydroxynaphthyl-*o*-hydroxy-*m*-toluic acid (*Epicarin*).
Neoquinophan.	6-Methyl-2-phenyl-quinoline-4-carboxylic ethyl ester
Novarsenobenzol.	Sodium 3 : 3'-diamino-4 : 4'-dihydroxy-1-arseno-benzene formaldehyde sulphoxylate (*Neosalvarsan*).
Novosulphexine.	Secondary hexamethylene salicyl sulphonate (*Neohexal*).
Orthocaine.	*m*-Amino-*p*-hydroxybenzoic methyl ester (*Orthoform*).
Oxoquin.	Hydroxyquinoline sulphate (*Chinosol*).
Paradrin.	Ethylamino-acetocatechol (*Homorenon*).
Phenacetin, B.P.	*p*-Acetylphenetidine.
Phenaspetin.	Aminoacetyl-phenetidine acetylsalicylate (*Aspirophen*).
Phenazone, B.P.	Phenyl-dimethyl-pyrazolone (*Antipyrin*).
Phenazopirin.	Antipyrine acetylsalicylate (*Acetopirin*).
Phenocaine hydrochloride.	Phenetidyl-acetphenetidine hydrochloride (*Holocain hydrochloride*).
Phenocitrin.	*p*-Phenetidine citrate (*Citrophen*).
Phenomine hydrochloride.	*p*-Hydroxyphenyl-ethylamine hydrochloride (*Tyramine*).
Phenosalin.	Salicyl-*p*-phenetidine (*Malakin*).
Piperazenyl.	Ethylene-ethenyldiamine (*Lysidine*).
Piperazidin.	Diethylene-diamine (*Piperazine*).
Proflavine.	3 : 6-Diamino-acridine sulphate.
Propocaine.	*p*-Aminobenzoic propyl ester (*Propœsin*).
Pyroxylin, B.P.	Dinitrocellulose.
Quinalgen.	*o*-Ethoxy-*ana*-benzoylaminoquinoline.
Quinophan.	Phenylquinoline carboxylic acid (*Atophan*).
Resiosol.	Bismuth iodoresorcinol sulphonate (*Anusol*).
Sal Alembroth.	Mercuric ammonium chloride $HgCl_2(NH_4Cl)_2H_2O$.
Salicylsuccinate.	Succinyl-disalicylic acid (*Diaspirin*).
Saliglycol.	Monoglycol ester of salicylic acid (*Spirosal*)
Salol, B.P.	Phenyl salicylate.
Sigmaform.	Bismuth tribromophenate (*Xeroform*).
Scarlet red.	Amino-azo-toluene β-naphthol.
Sinetide.	Thiosinamine ethyl iodide (*Iodolysin*).
Sodium acetylarsanilate.	Sodium acetylaminophenyl arsonate (*Arsacetin*).

Sodium aminarsonate.	Sodium aminophenylarsonate (*Soamin*).
Sodium metharsenite.	Disodium methyl arsinate (*Arsinyl*).
Sodium barbitone.	Sodium diethylbarbiturate (*Veronal-sodium*).
Sodium phenylbarbital.	Sodium phenylethylbarbiturate (*Luminal-sodium*).
Sozionic acid.	Di-iodo-*p*-phenol sulphonic acid (*Sozoiodol*).
Sulphamipyrin.	Sodium phenyldimethylpyrazolone-amino-methane sulphonate (*Melubrin*).
Sulphexine, Sulphexet.	Hexamethylenetetramine salicyl sulphonic acid (*Hexal, Hexalet*).
Sulphiolinic acid.	*m*-Iodo-*o*-hydroxyquinoline sulphonic acid (*Loretin*).
Sulphocol.	Potassium-guaiacol sulphonate (*Thiocol*).
Sulphonal, B.P.	Diethylsulphone-dimethyl methane.
Tartradine.	Dimethylpiperazidine tartrate (*Lycetol*).
Tetranitrin.	Erythrol tetranitrate.
Theosate.	Theobromine sodium and sodium lactate (*Theolactin*).
Thiosinamine.	Allyl thiourea $NH_2.CS.NH.C_3H_5$.
Thiosinyl.	Thiosinamine sodium salicylate (*Fibrolysin*).
Triketol.	Phenyl-1 : 2-triketocyclopropane hydrate (*Ninhydrin*).
Trinitrin, B.P.	Nitroglycerin.
Tripyrate.	Pyrogallol triacetate (*Lenigallol*).
Trypaflavine.	See *Flavine.*
Uracetin.	Acetyl-*p*-ethoxyphenyl urethane (*Thermodine*).
Uradal.	Brom-diethyl acetyl urea (*Adalin*).
Uvaleral.	Monobromo-isovaleryl-urea (*Bromural*).
Valide.	Valeryl-diethylamide (*Valyl*).
Valinopyrin.	Valeryl-amino-antipyrin (*Neopyrin*).
Valothalein.	Iso-valeryl-acetyl-phenolphthalein (*Aperitol*)

Trade Names of Drugs.

Abrasol. — Calcium β-naphthol α-monosulphonate, $(C_{10}H_6(OH) SO_3)_2Ca$. Antipyretic.

Acetal.—Ethylidene diethyl ether, $CH_3.CH(OC_2H_5)_2$. Hypnotic.

Acetocaustin.—Trichloracetic acid. Caustic.

Acetopyrine.—Antipyrine acetosalicylate.

Acetozone.—Mixture of equal parts of acetyl benzoyl peroxide, $(C_6H_5CO.O.O.C_2H_3O)$ and kieselguhr.

Achibromin.—Monobromoisovalerylglycolylurea, $CH_2(OH).CO.NH.CO.NH.CO.C_4H_8Br$, (28·5% Br).

Achiodin.—Monoiodoisovalerylglycolylurea (40% I).

Acoine.—Di-*p*-anisylmonophenetylguanidine hydrochloride, $C_2H_5OC_6H_4N : C(NHC_6H_4OCH_3)_2$. Cocaine substitute.

Actol.—Silver lactate.

Adalin.—Bromodiethylacetdurea   Hypnotics.

Adrenalin, Adrenal, Adrenamine, Adnephrin, Adrin.—Products of suprarenal gland, natural or synthetic. See Adrenine ("Alkaloids").

Afridol.—Sodium hydroxymercuric-*o*-toluate, $CH_3.C_6H_3(CO_2Na)HgOH$.

Agurin.—Addition product of theobromine-sodium and sodium acetate $C_7H_7N_4O_2Na, C_2H_3O_2Na$. Diuretic.

Airol, Airoform, Airogen.—Bismuth hydroxyiodogallate. $C_6H_2(OH)_3COOBiOH$.

Albargin.—Gelatose-silver (15% Ag.).

Aletodin.—Acetylsalicylic acid.

Aleudrin.—Carbamic acid ester of *aa*-dichloroisopropyl alcohol, $(CH_2Cl)_2.CH.O.CO.NH_2$.

Allosan.—Santalyl allophanate, $NH_2.CO.NH.CO_2.C_{15}H_{23}$.

Alphogen, Alphozone.—Succinyl peroxide, $(COOH.CH_2.CH_2.CO)_2O_2$.

Alumnol.—Aluminium salt of β-naphthol disulphonic acid, $[C_{10}H_5(OHSO_3)_2]_3Al_2$. Antiseptic.

Alypin.—Tetramethyl-diamino-dimethyl-ethyl-carbinyl-benzoate hydrochloride $C_6H_5.CO.O(C_2H_5)C[CH_2.N(CH_3)_2]_2$, HCl. Local anæsthetic.

Amarin.—Triphenyldihydroglycoxaline,

$$C_6H_5.C.NH \atop C_6H_5.C.NH \Big\rangle CH.C_6H_5.$$

Aminoform.—Hexamethylenetetramine.

Ammonol.—Ammoniated phenylacetamide.

Amphotropin.—Hexamethylenetetramine camphorate, $(C_6H_{12}N_4)_2$ $C_8H_{14}(COOH)_2$.

Amyloform.—Compound of formaldehyde and starch.

Anæsthesin, Anæsthone.—Ethyl ester of *p*-aminobenzoic acid, $NH_2.C_6H_4.CO_2C_2H_5$.

Analgen.—8-Ethoxy-5-monobenzoylaminoquinoline or 1-ethoxy-4-acetylamino quinoline.

Analgesine.—Antipyrine.

Analutos.—Calcium acetylsalicylate.

Anogon.—Mercury salt of 2.6-di-iodophenol-4-sulphonic acid. $C_6H_2I_2(OHg) (SO_2Hg)$.

Antikamnia.—Formerly acetanilide and alkali carbonates, now phenacetin.

Anglopyrin.—Acetylsalicylic acid.

Antiluetin.—Potassium-ammonium-antimony bitartrate, $[SbO(C_4H_4O_6)_2KNH_4]_2H_2O.$

Antisepsine.—*p*-Bromoacetanilide.

Antiseptol.—Cinchonidine iodosulphate.

Aponal.—Amylene carbamate, $NH_2.COOC_6H_{11}.$

Apyron.—Lithium acetylsalicylate.

Argaldin.—Combination of albumin silver and hexamethylenetetramine (10% Ag.).

Argentamine.—Ethylene-diamine-silver phosphate.

Argoferment.—Colloidal silver.

Argulan.—Mercury compound of dimethylphenylpyrazolonesulphamine, $C_{11}H_{11}N_2O.NH.SO_2HgOH.$

Argyrol.—Silver and vitellin compound (20—30% Ag).

Aristol.—Dithymol di-iodide.

Aristoquinine (Aristochin).—Carbonic ester of quinine, $CO(OC_{20}H_{23}N_2O)_2.$

Arrhenal.—Sodium methylarsinate, $AsO(CH_3)(ONa)_2$, 6 $H_2O.$

Arsacetin.—Sodium *p*-acetylaminophenylarsonate $C_2H_3O.NH.C_6H_4AsO(ONa)(OH),$ **5** $H_2O.$

Arsacetin-quinine.—Contains 43% arsacetin and 54% quinine.

Arsalyt.—Bismethylaminotetra aminoarsenobenzene.

Aseptol.—*p*-Phenolsulphonic acid (33% soln.).

Aspirin.—Acetylsalicylic acid.

Aspirin (soluble).—Calcium acetylsalicylate.

Aspirophen.—Aminoacetphenetidine acetylsalicylate, $C_2H_5O.C_6H_4.NH.C_2H_3O.NH_2$, $C_2H_3O.OC_6H_4.COOH.$

Asquirrol.—Mercury dimethoxide, $(CH_3O)_2Hg.$

Asubhil.—Mercury salt of atoxyl, $[NH_2C_6H_4.AsO.(OH)O]_2Hg.$

Atophan.—2-Phenylquinoline-4-carboxylic acid, $C_9H_5N(C_6H_5)COOH.$

Atoxyl.—Sodium *p*-aminophenylarsinate, $C_6H_7NAsO_3Na$, 4 H_2O (24% As).

Benzosalin.—Methyl-benzoyl salicylate, $C_6H_4(O.CO.C_6H_5)COOCH_3.$

Benzosol.—Benzoyl guaiacol, guaiacol benzoate.

Betol.—β-Naphthyl ester of salicylic acid.

Bismutose.—Compound of bismuth 22% and albumin 66%.

Bornyval.—Bornyl isovalerate, $C_4H_9CO.O.C_{10}H_{17}.$

Bornyval, New.—Bornyl isovaleryl glycollate, $C_4H_9COOCH_2.COOC_{10}H_{17}.$

Brometone.—Tribromo tertiary butyl alcohol, $CBr_3.C(CH_3)_2OH.$

Brominol, Brominoleum.—Brominated Sesame oil (33% Br)

Bromipin.—10% and 33½% Br.—Bromine addition compounds of Sesame oil.

Bromoglidin, Bromogluten, Bromoprotein.—Gluten or protein compounds of bromine.

Bromovalidol.—Validol with sodium bromide. Sedative.

Bromural.—*a*-Bromoisovalerylurea, $C_4H_8Br.CO.NH.CO.NH_2.$

Brophenin.—Bromoisovalerylphenocoll, a brominated phenetidine derivative.

Cacodyliargol.—Guaiacol cacodylate, $(CH_3)_2AsO.O.C_6H_4(OCH_3)$, $H_2O.$

Calomelol.—Colloidal calomel, $(Hg_2Cl_2).$

Chloralamide.—Chloralformamide, $C_3H_4Cl_3NO_2.$

Chloralose.—Anhydroglucochloral, $C_8H_{11}Cl_3O_6$, condensation product of chloral and glucose.

Chloretone.—Trichloro-tertiary-butyl alcohol, $CCl_3.(CH_3)_2C.OH$, ½ $H_2O.$

Chromoform.—Compound of methylhexamethylenetetramine and dichromic acid $(C_6H_{12}N_4CH_3)_2Cr_2O_7.$

Chrysoform.—Dibromo-di-iodohexamethylenetetramine, $C_6H_8Br_2I_2N_4.$

Citarin.—Sodium anhydromethylenecitrate. Gout specific.

Citrophene.—Triphenetidine citrate or citro *p*-phenetidine.

Colchi-sal.—Colchicine salicylate. Gout specific.

Coryfin.—Menthyl ethyl glycollate, $CH_2O(C_{10}H_{19}).COOC_2H_5$.

Coxpyrin.—Acetosalicylic acid.

Creolin.—A cresol emulsion.

Cresolin, Creosotal.—Creosote carbonate, carbonic esters of guaiacol and creosote

Cryogenin.—*m*-Benzaminosemicarbazide.

Cupratin.—Copper albuminate.

Cuprol.—Compound of nucleinic acid and copper.

Cutal, Cutol.—Aluminium borotannate.

Cycloform.—Isobutyl ester of *p*-aminobenzoic acid, $C_6H_4(NH_2)COOC_4H_9$.

Cystopurin.—Compound of hexamethylenetetramine and sodium acetate
$$C_6H_{12}N_4, 2 C_2H_3O_2Na, 6 H_2O.$$

Dermatol.—Bismuth subgallate.

Dermogen.—Zinc peroxide.

Dermol.—Bismuth chrysophanate.

Diabetin.—Lævulose.

Diogen.—Acetylene dichloride, CHCl : CHCl.

Diogenal.—Dibromopropyldiethylbarbituric acid,
$$(C_2H_5)_2C{<}{\begin{smallmatrix}CO.N(C_3H_5Br_2)\\CO————NH\end{smallmatrix}}{>}CO.$$

Dionin.—Ethyl morphine hydrochloride. Sedative.

Dioxygen.—A 3% solution of hydrogen peroxide.

Diplosal.—Salicylosalicylic acid, $HO.C_6H_4.CO.O.C_6H_4.COOH$.

Dispermin.—Piperazine NH : $(CH_2.CH_2)_2$: NH. Uric acid solvent.

Diuretin.—Theobromine sodium salicylate. Diuretic.

Dormiol.—Amylene hydrate and chloral compound. Hypnotic.

Duotol.—Guaiacol carbonate.

Ehrlich-Hata " 606 " *and* " 614."—Salvarsan and neosalvarsan.

Elarsone.—Strontium chloro-arseno-behenolate (13% As)

Electargol.—Electrolytic colloidal silver.

Empirin.—Acetylsalicylic acid.

Eosote.—Creosote valerate.

Epicaine.—Solution of epinine and cocaine hydrochloride

Epicarine.—Hydroxynaphthyl-*o*-hydroxytoluic acid.

Epinine.—3.4-Dihydroxyphenylethylmethylamine,
$$(HO)_2C_6H_3.CH_2.CH_2.NH.CH_3.$$

Epinephran, Epirenan.—See *Adrenin.*

Epinephrine.—*o*-Dihydroxy-4-methylaminoethanolbenzene,
$$(HO)_2C_6H_3.CH(OH).CH_2.NH.CH_3.$$

Eptosine.—1-Methyl-4.5-diphenyleneimidazole

Ergamine.—See *Histamine.*

α-Eucaine.—N.-methyl-benzoyl-triacetone-alkamine carboxylic acid methy-
ester, $(CH_3)_2C.CH_2$

$$CH_3.\ N\ C{<}{\begin{smallmatrix}COOCH_3\\O.CO.C_6H_5\end{smallmatrix}}\quad,\text{ superseded by }\beta\text{-eucaine.}$$
$$(CH_3)_2C.CH_2$$

β-Eucaine.—Benzoyl-vinyl-diacetone alkamine,
$$(CH_3)_2C\ .\ CH_2$$
$$H.N\quad CH.O.CO.C_6H_5\qquad\text{Local anæsthetic.}$$
$$CH_3\ .\ CH.CH_3$$

Eudermol.—Nicotine salicylate. Parasiticide.

Erphpine.—Apomorphine methyl bromide.

Euquinine.—Quinine ethyl carbonate. Tasteless quinine salt.

Euresol.—Resorcinol acetate, $C_6H_4(OH)(O.C_2H_3O)$.

Europhen.—Isobutyl-*o*-cresol iodide. Odourless antiseptic. Antipyretic.

Exalgin.—Methyl acetanilide, $C_6H_5.N(CH_3).CO.CH_3$.

Ferratogen, Ferrinol.—Iron nucleinate; contains 21% Fe_2O_3.

Fibrolysin.—15% soln. of combination of thiosinamine (2 mols.) and sodium salicylate (1 mol.).

Formalin.—A 40% solution of formaldehyde.

Formin.—Hexamethylenetetramine.

Galyl.—Tetraoxydiphosphaminodiarsenobenzene (35·3% As).

Geoform.—Condensation product of guaiacol and formaldehyde.

Geosote.—Guaiacol valerate.

Glidine.—Preparations of wheat protein.

Glutol, Glutoform, Glutoid.—Formaldehyde-gelatine.

Glycosal.—Salicylic ester of glycerol, $C_3H_5(OH)_2.O.CO.C_6H_4(OH)$.

Gynoval.—Isobornylisovalerate, $C_4H_9.COOC_{10}H_{17}$.

Hæmogallol.—Obtained by the action of pyrogallol on defibrinated blood.

Hectine.—Sodium benzosulpho-*p*-aminophenylarsinate,
$$C_6H_5.SO_2NA.C_6H_4.AsO(OH)(ONa).$$

Hedonal.—Methylpropylcarbinol urethane, $CH_3.CH_2.CH_2.CH(CH_3)O.CO.NH_2$.

Helicon.—Acetylsalicylic acid.

Helmitol—Hexamethylenetetramine-anhydromethylene citrate,
$$C_6H_{12}N_4, \quad C_7H_8O_7.$$

Hemisine.—Adrenine.

Heroin.—Diacetylmorphine, $C_{17}H_{17}NO_3(CH_3CO)_2$.

Hetoform.—Basic bismuth cinnamate, $(C_6H_5.CH:CH.COO)_2Bi, Bi_2O_3$

Hetol.—Sodium cinnamate. $C_6H_5.CH:CH.COONa$.

Hetralin.—Compound of resorcinol and hexamethylenetetramine,
$$C_6H_{12}N_4, \quad C_6H_4(OH)_2.$$

Hexal, Hexalet.—Hexamethylenetetramine salicylsulphonic acid.

Hexanatrine.—Compound of hexamethylenetetramine and acid sodium phosphate.

Histamine.— β-Iminazolylethylamine.

Holocain.—*p*-Diethoxyethenyldiphenylamidine.

Hopogan.—Magnesia with 15 or 25% MgO_2.

Hydropyrin.—Lithium acetylsalicylate.

Hydrosol.—Aqueous colloidal silver solution.

Hypnal.—Chloral antipyrine.

Hypnogen.—Diethylbarbituric acid.

Hypnone.—Acetophenone, $CH_3.CO.C_6H_5$.

Ichtammon, Ichden, Ichthyodine, Ichthyoson.—Ichthyol *q.v.*

Ichthargon.—Silver ichthyol sulphonate (30% Ag).

Ichthermol.—Mercury compound of ichthyol.

Ichthoform.—Compound of ichthyol and formaldehyde.

Ichthyalbin.—Compound of ichthyol and albumen.

Ichthyol (Ammon).—Ammonium salts of sulphonic acids of ichthyol—an oily product of destructive distillation of a bituminous schist from the Tyrol.

Ichthyolate.—Sodium salt of above.

Indoform.—Salicylic methylene acetate; from formaldehyde and acetylsalicylic acid.

Iodal, Iodol.—Tetraiodopyrrole, $\begin{matrix} CI:CI \\ | \quad \quad \rangle NH. \\ CI:CI \end{matrix}$ Iodoform substitute.

Iodinol.—Iodised sesame oil.

Iodipin.—Addition compound of Sesame oil containing 10% or 25% I.

Iodoglidin.—Preparation of wheat gluten containing 10% iodine.

Iodoglobin.—Di-iodotyrosine, $HO.C_6H_3I_2.CH_2.CH(COOH)NH_2$.

Iodolen.—Combination of iodol (tetra-iodopyrrole) and albumin (30% iodol).

Iodolysin.—Similar to tiodine contains 43% thiosinamine and 47%

Iodophenin.—Tri-iodo phenacetin.

Iodoval.—Mono-iodoisovalerylurea, $(CH_3)_2 CH . CHI . CO . NH . CO . CH_2$.

Iodozol.—Di-iodo-*p*-phenolsulphonic acid, $C_6H_2I_2(OH)SO_3H,3H_2O$.

Iodylin.—Bismuth iodosalicylate.

Iothion.—Di-iodoisopropyl alcohol, $CH_2I.CH(OH).CH_2I$.

Isopral.—Trichloro-isopropyl alcohol, $CCl_3.CH(OH).CH_3$.

Istin.—Synthetic anthraquinone derivative. Laxative.

Joha.—Oily suspension of salvarsan (40%) in iodipin.

Jothion.—See *Iothion.*

Kalmopyrine.—Calcium acetylsalicylate, $(C_6H_4O.CO.CH_3COO)_2Ca$.

Kephaldol.—Preparation of phenetidine and salicylic and citric acids in tablets.

Kharsine.—Sodium–*p*-amino-*m*-tolyl arsinate.

Kharsivan.—Dihydroxydiaminoarsenobenzene dihydrochloride, $HCl.NH_2(OH)C_6H_3. As: As. C_6H_3(OH)NH_2.HCl, 2 H_2O$. Antisyphilitic.

Koryfin.—See *Coryfin.*

Lacteol, Lactigen, Lactilloids, Lactobaccilline, Lactone.—Preparations of lactic acid baccilli.

Lactol.—β-Naphthol lactic ester.

Laxans, Laxatol, Laxen, Laxoin.—Phenolphthalein *q.v.*

Lenigallol.—Pyrogallol tri- or tetra- acetate.

Levurine, Levuretin, Levurinose.—Dried yeast.

Lithium-diuretin.—Addition product of theobromine lithium and lithium salicylate.

Lodal.—6-7 Dimethoxy 2-methyl-3.4-dihydro-isoquinolium chloride. Styptic.

Luesan.—Glidine preparation of mercury.

Luminal.—Phenyl methyl malonyl urea, Hypnotic.

$$C_6H_5 \Big\rangle C \Big\langle \begin{matrix} CO.NH \\ CO.NH \end{matrix} \Big\rangle CO.$$

Luminal sodium.—Soluble sodium salt of above.

Lysidine.—Ethylene ethenyl diamine, Diuretic

$$\begin{matrix} CH_2.N \\ | \\ CH_2.NH \end{matrix} \Big\rangle C.CH_3.$$

Lysoform.—A liquid formaldehyde potassium soap.

Lysol, Lysitol.—Creosol emulsified with soap.

Malonal.—Diethylbarbituric acid. Hypnotic.

Maretin.—*m*-Tolylsemicarbazide, $CH_3.C_6H_4.NH.NH.CONH_2$.

Medinal.—Sodium compound of diethyl barbituric acid. Hypnotic.

Melubrin.—Phenyldimethyl pyrazolone aminomethanesulphonic acid ; sodium salt. $C_{11}H_{11}N_3ONHCH_2SO_3Na$.

Mercuriocoleolo, Mergal, Mejodin, Merlusin, Merchinol, Mercoid.—Organic compounds of mercury.

Mercurol.—Mercury compound of nucleinic acid.

Mesotan.—Salicylic methoxymethyl ester, $C_6H_4.OH.COOCH_2.OCH_3$. Antirheumatic.

Methylrhodin.—Methyl acetylsalicylate, $C_2H_3O.O.C_6H_4.CO_2.CH_3$.

Metramine.—Hexamine.

Migrainine.—Compound containing 9% caffeine, 90% antipyrin, and 1% citric acid.

Migralgine.—Mixture of antipyrine 88, caffeine 9, and salicylic acid fused together.

Monotal.—Guaiacol methyl glycollate, $CH_2(OCH_3).COOC_6H_4.OCH_3$. Antipyretic and antiseptic.

Morphosan.—Morphine methyl bromide, $C_{17}H_{19}NO_3.CH_3Br, H_2O$. Anæsthetic.

Mydriasine.—Atropine methyl bromide, $C_{17}H_{23}NO_3.CH_3Br$. Mydriatic.

Naphthosalol, Naphthalol.—β-Naphthyl salicylate, $C_6H_4OH.COO.C_{10}H_7$. Intestinal antiseptic.

Narcyl.—Ethyl narceine hydrochloride, $C_{23}H_{26}(C_2H_5)NO_8.HCl$.

Nargol.—Silver compound of nucleinic acid (10% Ag).

Neoform.—Bismuth compound of tro-iodophenol, $C_6H_2I_2OBi(OH)_2, Bi_2O_3$

Neohexal.—Secondary hexamethylenetetramine sulphosalicylate. Urinary antiseptic.

Neokharsivan—Sodium 3.3'-diamino-4.4'-dihydroxyarsenobenzene-formaldehyde sulphoxylate, $NH_2.C_6H_4(OH)As.As.C_6H_3(OH)NH(CH_2O)SO_2Na$. Antisyphilitic.

Neolysol.—Lysol made with chlorcresol.   Odourless antiseptic.

Neopyrin.—Valerylamino-antipyrine.

Neosalvarsan.—See *Neokharsivan.*

Nizin.—Zinc sulphanilate, $(C_6H_4.NH_2SO_3)_2Zn$.

Novargan.—Protein compound containing 10% silver.

Novaspirin.—Methylenecitrylsalicylic acid.

Novocaine.—p-Aminobenzoyldiethylaminoethanol hydrochloride, $NH_2.C_6H_4CO.O.CH_2.CH_2.N(C_2H_5)_2HCl$.

Nucleogen.—Nucleinic compound of iron containing arsenic.

Orsudan.—Sodium methyl acetyl-p-aminophenylarsinate, $C_2H_5O.NH.C_6H_3(CH_3).AsO(OH)(ONa)$.

Orthoform.—p-Amino-m-hydroxy-benzoic-methyl-ester.

Orthoform, New.—m-Amino-p-hydroxy-benzoic-methyl-ester.

Parolein.—Refined petroleum, Sp. Gr. ·885.

Perborax, Perborin, Perboral.—Sodium perborate.

Perhydrit.—Hyperol, 30% H_2O_2.

Perhydrol.—Solution of hydrogen peroxide containing 30% H_2O_2 or 100 vols. available O.

Peronine.—Benzylmorphine hydrochloride, $C_{17}H_{18}NO_2.O.C_6H_5.CH_2, HCl$.

Phenalgin.—Phosphoammoniaacetanilide.

Phenamine.—Amino-aceto-p-phenetidin hydrochloride, $C_2H_5O.C_6H_4.CO.CH_2.NH_2.HCS$.

Phenoval.—Bromovalerylphenetidin, $C_4H_8Br.CO.NH.C_6H_4.OC_2H_5$.

Picrastol.—Dimethylol-diformyl-methenyl-tetramethylene-pentamine, $C_9H_{17}N_5O_4$.

Piperazine.—Diethylene-diamine, $HN \begin{array}{c} CH_2.CH_2 \\ CH_2.CH_2 \end{array} NH$.   Uric acid solvent.

Proponal.—Dipropylbarbituric acid, $(C_3H_7)_2C \begin{array}{c} CO.NH \\ CO.NH \end{array} CO$.   Hypnotic.

Protargol.—Protein compound of silver (8% Ag).

Pyoktanin.—Methyl violet, $[C_6H_4N(CH_3)_2]_2(C_6H_4.NH.CH_3)CCl$.   Antiseptic.

Pyramidon.—Dimethylaminoantipyrine.

Quinoform.—Quinine formate, $C_{20}H_{24}N_2O_2$, $HCOOH$; also a condensation product of cinchotannic acid and formaldehyde.

Rhodaform.—Hexamethylene-tetramine-methyl-sulphocyanide, $C_6H_{12}N_4.CH_3.CNS$.

Sabromine.—Calcium dibromobehenate (29% Br), $(C_{22}H_{41}O_2Br_2)_2Ca$.

Sajodin.—Calcium mon-iodobehenate, $(C_{22}H_{41}O_2I_2)_2Ca$.

Saletin.—Acetyl salicylic acid.

Saliformin.—Hexamine salicylate.

Salit.—Bornyl salicylate, $C_6H_4.OH.COO.C_{10}H_{17}$.

Salophen.—Acetyl-para-aminophenol, $HO.C_6H_4.NH.CO.CH_3$, salicylic ester.

Salufer.—Sodium silicofluoride, Na_2SiF_6.   Antiseptic.

Salvarsan.—See *Kharsivan.*

Sidonal.—Urea quinate.

Sidonal New.—A mixture of quinic acid, $C_6H_7(OH)_4COOH$ (25%) and its anhydride (75%).   Gout specific.

Soamin.—Sodium arsanilate, $NH_2.C_6H_4.AsO(OH)(ONa)$, 5 H_2O.

Solurol.—Thyminic acid (nucleotinphosphoric acid), $C_{30}H_{46}N_4O_{15}(P_2O_5)_2$. Uric acid solvent.

Sophol.—Silver formonucleinate.

Sozoiodol.—Di-iodophenol sulphonic acid.

Spirarsyl.—Sodium salt of arsenophenylglycine, $(CO_2Na.CH_2.NH.C_6H_4)_2As_2$.

Spirosal.—Glycol ester of salicylic acid, $HO.C_6H_4.COO.CH_2.CH_2.OH$. Antirheumatic.

Stovaine.—Dimethyl-amino-tertiary-amyl-benzoate hydrochloride, $C_6H_5COO.C(CH_3)(C_2H_5)CH_2N(CH_3)_2HCl$.   Local anæsthetic.

Stypticine.—Cotarnine hydrochloride.   Styptic.

Styptol.—Cotarnine phthalate.   Styptic.

Sublamine.—Mercuric ethylene diamine sulphate (43% Hg).   Antiseptic.

Somatose.—Meat albumose (semi-digested proteid).

Supradin, Suprarenalin, Suprarenin.—Adrenalin *q.v.*

Taka-diastase.—Enzyme from the fungus, *Eurotium oryzæ*, grown on rice.

Tannalbin.—A compound of tannin with albumen.   Intestinal astringent.

Tannigen.—Diacetyl tannin, $C_{14}H_8(COCH_3)_2O_9$.   Intestinal astringent.

Tannoform.—Compound of tannin with formaldehyde, $C_{29}H_{20}O_{18}$.

Tanocol.—Compound of tannin and gelatine.   Intestinal astringent.

Tenosin.—Preparation of active principles of ergot, containing β-iminazoly ethylamine (0·05%) *p*-hydroxyphenylethylamine (2%).

Tetronal.—Diethyl-methane-diethylsulphone, $(C_2H_5)_2 : C : (SO_2.C_2H_5)_2$.   Hypnotic.

Theocin.—Theophylline (synthetic), see Alkaloids.

Theocin-sod. acetate.—Theophylline sodium acetate.   Diuretic.

Thiocol.—Potassium guaiacol sulphonate, $C_6H_3OCH_3OHSO_3K$.   In phthisis.

Thioform.—Basic dithio-salicylate of bismuth.

Thiol.—Artificial substitute for ichthyol.

Thiolin.—Similar to ichthyol.

Thyresol.—Santalol methyl ether, $C_{15}H_{23}O.CH_3$.

Tiodine.—Thiosamine ethyl iodide

$$S : C \begin{cases} NH.C_2H_5 \\ NH_2.C_2H_5.I \end{cases}$$

Trional.—Methyl sulphonal.

Tumenol.—Artificial substitute for ichthyol.

Tyramine.—*p*-Hydroxyphenylethylamine hydrochloride
$$HO.C_6H_4.C_2H_4.NH_2, HCl.$$

Uradal.—Bromodiethylacetylurea.

Urisol, Uritone.—See *Urotropin.*

Urol.—Urea compound of quinic acid.

Urosin.—Lithium salt of quinic acid, $C_6H_7(OH)_4COOLi$.

Urotropin.—Hexamethylene tetramine, $(CH_2)_6N_4$.   See Hexamine.

Urotropin New.—Helmitol.

Ursal.—Urea salicylate.

Validol.—Mentholisovalerianate, $C_4H_9.CO.O.C_6H_9.CH_3.C_6H_7$.   Sedative.

Valisan.—Bornylbromoisovalerianate, $C_4H_8Br.CO.OC_{10}H_{17}$.

Valyl.—Valeric diethylamide. $C_4H_9.CO.N(C_2H_5)_2$.

Vasogen.—Oxygenated petroleum.

Veronal.—Barbitone, diethylbarbituric acid, $(C_2H_5)_2 : C : (CO.HN)_2 : C :$ Hypnotic.

Vesipyrine.—Phenyl acetylsalicylate, $CH_3.CO.OC_6H_4.COOC_6H_5$.

Xaxa.—Acetylsalicylic acid.

Xaxaquin.—Quinine salt of acetylsalicylic acid,
$$C_{20}H_{24}N_2O_2, CH_3CO.OC_6H_4.COOH.$$

Xeroform.—Bismuth tribromophenolate.

Yohimbine.—See *Corynine* (Alkaloids).

Zinol.—Mixture of alumnol and zinc acetate.

GLOSSARY OF CERTAIN MEDICAL TERMS.

Alterative	Produces certain changes throughout the system which are not well understood.
Anæsthetic	Produces unconsciousness.
" (Local)	Causes local insensibility.
Anodyne	Relieves pain.
Analgesic	" "
Anthelmintic	Destroys intestinal parasites.
Antipyretic	Lowers temperature of the body.
Antiseptic	Acts against putrefactive micro-organisms.
Aseptic	Free from micro-organisms.
Astringent	Reduces secretion by contraction of the tissues.
Cathartic	Purgative.
Diaphoretic	Induces perspiration.
Diuretic	Increases secretion of urine.
Emetic	Causes vomiting.
Emmenogogue	Stimulates menstruation.
Expectorant	Promotes removal of bronchial secretion.
Febrifuge	Reduces body temperature in fever.
Galactogogue	Increases secretion of milk.
Hæmostatic	See *styptic*.
Hormone	Secretion of a gland exciting another organ.
Hypnotic	Induces sleep.
Hypodermic	Under the skin (as injections).
Intravenous	Into the veins (as injections).
Laxative	Mild purgative.
Mydriatic	Causes dilation of the pupil of the eye.
Myotic	Causes contraction of the pupil of the eye.
Narcotic	Diminishes mental activity.
Pressor	Causes rise of arterial pressure, usually by the constriction of the arterioles.
Pyretic	See *antipyretic*.
Sedative	Soothes the nerves.
Styptic	Arrests bleeding.
Sudorific	See *diaphoretic*.
Tæniafuge	Promotes expulsion of tæniæ (tape-worms).
Vermifuge	Promotes expulsion of worms.

INDIARUBBER.

Commercial India-rubber.

To prepare india-rubber for its various technical uses, the manufacturer has found it necessary in almost every case to vulcanise or " cure " the rubber by either :

(i) exposing it to the influence of sulphur at temperatures of 130°C. and upwards, if the rubber is in thick masses ;

or (ii) exposing it to the influence of sulphur monochloride (either in the form of vapour or as a dilute solution of S_2Cl_2 in carbon disulphide), at the ordinary temperature. This is only applicable where the rubber is in thin sheets or films.

To increase the resistance of certain rubber goods to the influence of heat, oils, or mechanical abrasion, it has been found advisable to incorporate in the " mixing " inorganic matter, generally oxides, carbonates, or silicates. In order to reduce the price of rubber goods, without increasing to an appreciable extent their specific gravity, additions are made of such organic filling agents as resins, oils, pitches, vegetable fibres, and, most important of all, fatty substitutes. These fatty substitutes are oils, either oxidised (*i.e.* " blown " oils) or vulcanised by heating with sulphur or treating with sulphur chloride. Reclaimed rubber and ground waste rubber are also added to decrease the cost, and in special cases where a peculiar dead toughness is required (*e.g.* in cab tyres), balata and gutta-percha are also added to the mixture.

The most important points to determine in a sample of rubber therefore are :

(i) India-rubber, recovered rubber, balata, and gutta-percha.

(ii) Organic matter other than rubber, including
Rubber resins, and added resins.
Free oil (mineral, fatty, and resin oil) ; also waxes.
Fatty substitutes (oxidised or vulcanised oils).
Bitumens, tars, pitches (including " mineral rubber ").
Vegetable fibres, and starches.

(iii) **Sulphur and chlorine in india-rubber.**
　　Sulphur and chlorine in substitutes (and in bitumens).
　　Free sulphur.
　　Sulphur in inorganic matter.
(iv) **Inorganic matter.**

Sampling.

In preparing samples for analysis, constructive materials, such as cloth insertions, etc., must first be carefully removed. This is most readily carried out by saturating the fabric with benzene, when it may easily be stripped from the rubber. In the case of thin waterproof cloth the rubber must be scraped from the cloth with a palette knife after the usual treatment with benzene. The rubber so obtained must be dried in a steam oven before it is analysed.

Articles, such as cables, which contain rubbers of different composition, should be separated into their respective layers, and each of these analysed separately; at the same time the ratio of the weights of the different layers to that of the whole article should be determined.

Before analysis all samples should be reduced to a very fine state of division, both to facilitate the extraction with solvents and to ensure an average sample being obtained. This is done by passing the sample through a pair of " mixing rollers," by means of which all correctly vulcanised rubber goods, with rare exceptions, are reduced to a mass of fine flakes. This is repeated until a material sufficiently homogeneous for analysis is obtained. To reduce a sample to a fine state of division by rubbing down on a coarse file is more laborious, but, as such preparation precludes the possibility of altering the rubber hydrocarbons by " mastication " (and thereby increasing the figures for the acetone extract and the loss on saponification), this method should be adopted for all analyses where the highest degree of accuracy is required, and in all cases of research work on vulcanised samples.

ANALYSIS OF INDIA-RUBBER.

It is occasionally of importance to boil a small quantity of the sample with water, ascertain whether the solution has an acid or alkaline reaction, and whether, after filtering, it leaves a residue which can be further examined. Goods which have been vulcanised with sulphur chloride generally give an acid reaction, and yield sodium chloride in the aqueous extract if they contain " white substitute," in the manufacture of which sodium bicarbonate has been used.

The most suitable organic solvent for the oily and resinous

constituents of india-rubber is acetone, as it will readily dissolve these together with free sulphur and solid hydrocarbons without dissolving a trace of rubber, gutta-percha, or balata.

Acetone extract.

The acetone extraction is carried out in a Soxhlet apparatus of 25 cc. to 50 cc. capacity, using 1.5 to 2.0 grms. of the finely-ground sample contained in an extraction thimble. The reflux condenser is so arranged that the condensed acetone falls directly into the thimble. For ordinary samples the extraction is complete in about ten hours. The extract is finally dried at 100°C. and weighed. This extract contains :

> (i) Rubber resins.
>> Free oil from substitutes.
>> Free fatty, mineral, and resin oils
>> Resins, and Waxes.
>> Free sulphur.

The residual rubber still contains :
> (ii) India-rubber, gutta, and balata.
>> Oily substitutes.
>> Pitches, tars, and bitumens.
>> Sulphur of vulcanisation.
>> Sulphur in both organic and inorganic filling materials.
>> Chlorine in rubber and substitutes.
>> Inorganic constituents.

If the extract contains waxes or solid resins, even in small quantities, it will be no longer fluid, so that even a viscous liquid extract may safely be assumed to be free from these bodies. On adding 5 cc. of warm absolute alcohol to the extract, any thin liquid residue left undissolved consists of mineral oil. If the solution deposits voluminous flakes on cooling, the presence of wax is practically certain. The amount of fatty oil in the extract may be roughly estimated by saponifying the extracted matter with standard alcoholic potash, titrating the excess with hydrochloric acid, and calculating that 172 mgrm. of potash saponify 1 grm. of fatty oil (calculated as colza oil). The presence of well-shaped crystals of free sulphur in the extract always indicates the absence of oily or resinous ingredients other than those derived from the rubber, or of solid hydrocarbons. The estimation of the free sulphur in such a simple extract may be done by washing out the oily and resinous matter with five portions of 2 cc. of cold acetone, filtering each time into a weighed flask. The filter is washed with 5 cc. carbon

disulphide into the original flask. After the solvents have been driven off, the flasks are dried and the organic extract and sulphur respectively determined by weighing. An error is involved, due to the solubility of sulphur in acetone, to the extent of 5 mgrm. of sulphur in the 10 cc. of acetone used, so that the amount of sulphur must be increased and the organic extract reduced by this amount. In the case of complex extracts, the only satisfactory method for determining the free sulphur is to oxidise the whole of the extract with fuming nitric acid on a water-bath, dilute, filter if necessary wash, and finally precipitate the sulphuric acid with barium chloride.

For the determination of pitches, bituminous bodies, and "mineral rubbers," no satisfactory method is known, as these bodies vulcanise to varying extents, and thus become completely insoluble. The method suggested by C. O. Weber (see below) for their estimation is only useful in so far as it indicates their presence or absence by the colour of the extract *after the first five minutes*. On prolonged extraction with pyridine, as he suggests, all samples of rubber will give a coloured extract, even in the absence of bitumens, as most organic solvents have the power of attacking the vulcanised rubber at 120°C. In addition to this error the fact must be remembered that the vulcanised portion of the bitumen or pitch is scarcely attacked by boiling pyridine, and that therefore the figure given by this extraction has little or no meaning. As it is, however, the only method yet suggested, the following description from Weber is given :

Pyridine extract.

The extraction with acetone is immediately followed by an extraction with pyridine (B.P. 109°—112°C.), without any intervening drying of the extraction thimble or its contents. The flask is heated on an oil bath (not a sand bath), and kept at 116°—120°C. After extraction the outside of the flask is cleaned with filter paper moistened with benzene, and the flask heated in a water-oven till the smell of pyridine has disappeared. It is then allowed to cool and is weighed.

The estimation of sulphur in all the various forms in which it may occur in manufactured india-rubber being one of the most important points in the complete analysis, it therefore becomes necessary to estimate the sulphur in this extract.

To determine this sulphur, the pyridine extract is oxidised with fuming nitric acid in the flask in which it was weighed. When dissolved it is transferred to a small porcelain dish, the flask washed out with nitric acid, and the washings added to the dish. The liquid is concentrated to a syrupy consistency,

a small amount of sodium acetate added, and the evaporation continued to dryness. The mass is fused and the carbonaceous matter burned off with small additions of sodium nitrate, the melt being allowed to cool. It is then dissolved in water, filtered, washed, and the filtrate acidified with hydrochloric acid. The sulphuric acid formed is precipitated as barium sulphate in the usual manner.

Saponification.

The residue from the pyridine extraction is washed with acetone to remove the last traces of pyridine, and then examined for substitutes by Henrique's method. This consists of drying the residual sample, transferring to a wide-necked flask, and after adding about 25 cc. alcoholic potash (2N), heating on a water-bath with a reflux condenser for six or seven hours. The alcoholic liquor is poured off and preserved, the insoluble residue washed with boiling water till free from alkali, and the washings added to the alcoholic liquor. The residue is dried in an inert atmosphere (usually coal gas) to avoid oxidation, and when cool, weighed. The loss represents the weight of fatty substitutes removed by saponification. In all mixings containing zinc oxide, this treatment with alcoholic potash removes some of the zinc as potassium zincate. This must be estimated in the alcoholic liquors (see later), and a suitable correction made in the loss on saponification. This, like the other data, must be calculated on the weight of the original sample, and not on the weight of the sample of rubber saponified.

As the fatty substitutes present may be oxides, sulphides, or chloro-sulphides of triglycerides, or mixtures of these, it becomes necessary to ascertain which is present, and this is carried out by examination of the alkaline liquor from the saponification process. If of considerable volume, this is evaporated down and then made up with water to 150 cc. Of this 50 cc. are neutralised with concentrated hydrochloric acid, about 1 cc. excess of the acid added, and the zinc content determined by the ferrocyanide process (see Volumetric analysis, Vol. I). The zinc is calculated to zinc oxide and deducted from the total loss on saponification, giving the saponifiable organic matter. A further 50 cc. are taken and evaporated to dryness in a basin, ignited with a small amount of sodium nitrate, cooled, and the mass dissolved in water. On adding nitric acid and silver nitrate the chlorine present is precipitated as silver chloride, which is washed, ignited, and weighed. The chlorine thus found represents the chlorine present in chlorosulphide substitutes.

The remaining 50 cc. are boiled with bromine water and

concentrated to a thick syrup, which is oxidised with nitric acid (fuming), evaporated to dryness, and fused with sodium nitrate, the mass being then dissolved in water. The sulphuric acid present is determined in the usual manner as barium sulphate.

If chlorine and sulphur are both present, and approximately in the ratio of their atomic weights, the substitute present is a chloro-sulphide substitute either alone, or mixed with a " blown " oil substitute. If excess of sulphur be present the substitutes may be chloro-sulphide and sulphide, or a mixture of these with a " blown " oil substitute. In the absence of chlorine, no chloro-sulphide substitute can have been used, and the absence of both chlorine and sulphur prove that the substitute is entirely an oxidised or " blown " oil. A difficulty occurs in connection with this reasoning if a chloro-sulphide substitute is used in hot vulcanised articles, as is often the case, as some of the chlorine leaves the substitute (as hydrochloric acid) during vulcanisation and is absorbed by the rubber and basic inorganic constituents of the mixing. Sufficient chlorine, however, remains in the substitute for its detection.

As a result of saponification a further separation will have been made :

I. *Substance removed by Saponification, and estimated* :

    (a) Chloro-sulphide substitutes.
    (b) Sulphide substitutes.
    (c) Oxidised substitutes.
    (d) Chlorine in substitutes.
    (e) Sulphur in substitutes.

II. *Substances remaining in the Residue (Unsaponifiable)* .

    (a) India-rubber, gutta, and balata.
    (b) Fibres, carbon, etc.
    (c) Chlorine in rubber.
    (d) Sulphur of vulcanisation.
    (e) Sulphur in inorganic matter.
    (f) Inorganic matter.

Nitronaphthalene " extraction."

For the separation of the rubber from the inorganic constituents the most direct method is incineration. This answers quite well as a rapid works method for known samples, but is unsatisfactory for unknown samples, as it so interferes with the composition of the mineral matter as to render it impossible to determine its exact nature when originally added to the mixing.

To avoid this difficulty a separation may be effected by digesting the unsaponifiable residue with nitrobenzene or α-nitronaphthalene (M.P. 58°C.). These substances completely decompose vulcanised rubber at a temperature of 170°—180°C., nitrobenzene being satisfactory, however, only with samples containing up to 4 per cent. of combined sulphur, whereas nitronaphthalene applies to all cases up to 15 per cent. of combined sulphur, and even higher than this in most instances. The latter also yields solutions which, after diluting with benzene, filter more readily than those produced from the nitrobenzene treatment.

In employing this method it is always advisable to add to the nitrobenzene 8—10 per cent. of chloroform, which lowers the boiling point of the mixture from 208°C. to about 175°C., thereby preventing the carbonising action on the rubber of any red lead or ferric oxide present (a very marked result when the temperature exceeds 180°C., and one which increases the figure for "carbon black" in the final results, at the expense of the figure for "india-rubber"). In Weber's nitro-naphthalene method the addition of 5 per cent. of chloroform is also beneficial, although the boiling point is scarcely reduced by this addition. It therefore becomes necessary to heat the flask inside an air-bath fitted with a thermostat by means of which a steady temperature of 180°C. is maintained. The method of procedure in this case is to place the residue, the weight of which is known, in a wide-necked flask with 60—70 grm. α-nitronaphthalene and 3 or 4 cc. of chloroform, and arrange the flask in an air-bath, which almost completely surrounds it. The bath is kept at 180°C. for about an hour, or until solution is complete, when the flask is removed, allowed to cool, about 150 cc. benzene added, and the liquid left to stand for the mineral matter to settle out. The solution is filtered, washed with warm benzene, and dried in a steam-oven. The loss in weight represents rubber, gutta, and balata, together with sulphur and chlorine of vulcanisation. The residue contains the fibres (cotton, etc.), mineral constituents, and, in rare instances, starches. As the rubber, gutta, and balata in the solution are present in a decomposed condition, it is impossible to determine how much of each is present, or in fact, whether any gutta or balata has been used, or whether the rubber was new raw rubber, reclaimed rubber, or ground rubber waste. The best criterion as evidence of the presence of reclaimed or waste rubber is a high degree of vulcanisation in goods where such a figure would not be expected, especially when it occurs in conjunction with a very heterogeneous mineral content, carrying small

percentages of almost every mineral used by the rubber manufacturer.

On washing the residue from the nitronaphthalene extraction with boiling water, using about 200 cc. in all, all dextrine or soluble starch will be removed, and may be estimated.

Estimation of Vegetable fibres.

The fibrous matter in the residue is next removed by shaking a weighed quantity with chloroform. The mineral matter settles and the chloroform and most of the fibres are poured off into a dish. The mineral matter is again washed until free from fibres, the chloroform being then evaporated from the dish; the remaining fibres are transferred by means of a camel-hair brush to a watch-glass and weighed. From this weight the fibres present in the residue are calculated.

Estimation of Carbon black.

The carbon black in the residue may be determined (if present, as shown by the colour) by burning off part of the residue with lead chromate in the manner adopted for the elementary analysis of organic bodies containing sulphur. Graphite will also be found as "carbon" in this process.

Mineral Matter.

Both the qualitative and quantitative analysis of the inorganic constituents in the residue from the nitronaphthalene extraction follow the usual methods of inorganic analysis. The following list gives the minerals most frequently employed by the rubber manufacturer, and may have been added as such to the mixing together with the raw rubber, substitute, sulphur, and the like, or they may have found their way into the goods via the reclaimed rubber or ground rubber waste, with or without the knowledge of the manufacturer:

Whiting ($CaCO_3$).

Barytes ($BaSO_4$).

Zinc oxide (ZnO).

Lithopone ($ZnS + BaSO_4$).

French chalk ($Mg_3SiO_{12}H_2$).

Asbestos (Mg. Ca. Silicate).

Lime ($Ca(OH)_2$).

Magnesia (MgO).

China clay ($Al_2Si_2O_9H_4$).

Atmoid (SiO_2).

Magnesium carbonate ($MgCO_3$).

Gypsum ($CaSO_4.2H_2O$).

White lead ($Pb_3C_2O_8H_2$).

Red lead (Pb_3O_4).

Litharge (PbO).

Golden antimony ($Sb_2S_5 + S$).

Iron oxide (Fe_2O_3).

Vermilion (HgS).

Other substances found in special cases include :

Metallic filings.

Mica.

Powdered glass.

Powdered pumice.

Lead thiosulphate.

Zinc sulphide

In coloured goods which are hot vulcanised, the colours are produced by stable mineral pigments, which require detecting and estimating in the inorganic residue. The most usually employed are :

Antimony sulphide.	Zinc yellow.
Vermilion.	Hydrated chromium oxide.
Iron oxide.	Ultramarine.
Cadmium sulphide.	

For " cold cured " goods these colours are replaced by lakes (since in these goods they will not be called upon to withstand the action of molten sulphur and they also give brighter shades). These lakes are precipitated by a solution of alum in the presence of barium chloride, and consist of an aluminium lake of either an acid or basic colour, thrown down on a *blanc fixe* base. Their presence in a rubber mixing is shown by the coloration of the acetone extract. They may be extracted qualitatively with dilute solutions of

(a) alcoholic ammonia, in which the acid colours dissolve ;

(b) alcoholic acetic acid, in which the basic colours dissolve.

This should be performed in a test-tube, using a little of the original ground sample.

In many cases it is much more rapid, if not even absolutely necessary, to substitute for chemical analysis a microscopic examination of the insoluble portion of the mineral substances, provided that standard slides are prepared, and kept ready for comparison.

The determination of the sulphur in the inorganic matter is carried out by heating a weighed quantity with fuming nitric acid in a basin on a water-bath, taking the usual precautions to prevent loss through spirting, and concentrating to a syrupy consistency. Sodium acetate is added, the mass evaporated to dryness, and then fused with a small amount of potassium nitrate, allowed to cool, dissolved in boiling water, filtered and washed. Hydrochloric acid is added to the filtrate, and the sulphuric acid precipitated with warm barium chloride and treated in the usual manner. The percentage of sulphur in the mineral matter must be calculated on the initial weight of the original sample.

The amount of sulphide sulphur present in the mineral constituents may be determined by the method of Stevens. When the saponification is complete, a portion of the dry

residue is thoroughly swollen with a solvent such as ether, and treated with warm dilute hydrochloric acid. The hydrogen sulphide evolved is collected and estimated, giving the sulphide sulphur contained in such constituents as zinc sulphide or lead sulphide.

Determination of Sulphur and Chlorine.

The total sulphur is estimated by the method of Waters and Tuttle. About 1 grm. of the sample is treated at 70—80°C. with concentrated nitric acid saturated with bromine, and the liquor concentrated. This treatment is repeated two or three times, concentrated hydrochloric acid added, and the mixture boiled for a few minutes, and then diluted with water. The sulphuric acid formed is estimated in the usual manner.

For the estimation of the sulphur and chlorine combined with the rubber, the most satisfactory method is to extract about 1·5 grm. of the original sample successively with acetone, pyridine and alcoholic potash as before, and then take about 0·3 to 0·4 grm. of the residue for the chlorine estimation and the remainder of the residue for the sulphur estimation, which is performed in the same manner as the determination of total sulphur in the sample. This figure gives the sulphur of vulcanisation plus the sulphur in the inorganic matter, which has been previously determined, and from which the sulphur of vulcanisation may be calculated.

Chlorine is determined by Carius' method, employing 0·3-0·4 grm. prepared rubber (see above), which, together with 5 or 6 cc. fuming nitric acid and 1 grm. of silver nitrate, are heated together for two days in a sealed tube, then carefully opened. The contents are washed out with hot water, and filtered. If all the minerals present in the sample are soluble in nitric acid the precipitate is simply silver chloride, which may be treated and weighed as usual. In the presence of other insoluble matter, the precipitate is washed, dried, and transferred to a crucible, to which the filter-paper is added after incinerating. The contents of the crucible are then mixed with ten times their weight of sodium carbonate, and fused, the melt being cooled, dissolved in water, and filtered. The residue is washed, and then rinsed into a dish, 50 cc. of hot dilute nitric acid being added to the dish by allowing to flow through the filter. The contents of the dish are heated for about ten minutes at near boiling point, filtered, and the residue washed thoroughly until free from acid. To the filtrate is added a slight excess of hydrochloric acid, and the silver chloride is filtered off, washed, ignited, and weighed. From this weight the chlorine in the rubber can be calculated.

A summary of this system for the complete analysis of a vulcanised rubber sample may be drawn up as follows :

I. *Extraction with acetone.*
Rubber resins, oils (fatty, mineral, and resin oils), waxes, resins, and free sulphur.

II. *Extraction with pyridine.*
Tars, bitumens, and pitches (and sulphur in the same).

III. *Extraction with alcoholic potash.*
Substitutes (sulphide, chloro-sulphide, and oxidised oils). Sulphur and chlorine content.

IV. *Extraction with nitronaphthalene.*
India-rubber, including chlorine and sulphur of vulcanisation (by loss in weight).

V. *Extraction with boiling water.*
Starch and dextrine.

VI. *Washing with chloroform.*
Fibrous matter.

VII. *Examination of residue.*
For carbon, mineral matter, and sulphur in inorganic constituents.

VIII. *Separate determination of total sulphur.*

IX. *Separate determination (after III) for sulphur of vulcanisation.*

X. *Separate determination (after III) for chlorine of vulcanisation.*

A complete analysis is rarely carried out on a sample of rubber, and in practice it is only usual to perform four or five estimations. If, for example, the minerals contain no sulphur in any form, a considerable shortening of the analysis is possible. Moreover, red rubbers, grey rubbers, and drab rubbers contain no pitches, and so Extraction II is unnecessary. Extraction IV may also be eliminated, the rubber being determined by difference. The mineral matter is very frequently determined by incineration, which involves an error, with the most careful working, of up to 2–3 per cent. ; but as this only affects the figures for india-rubber and mineral matter, it is not, in the majority of cases, of practical importance.

It should be noted here that in carrying out an ash test on a rubber, the sample should never actually burn, but rather distil, until all evolution of vapours has ceased, when a larger flame may be used, and the carbonaceous matter burned off.

ANALYSIS OF EBONITE.

As ebonite, or vulcanite, is merely a very highly vulcanised rubber, its analysis follows the methods already indicated for the analysis of india-rubber. There are, however, one or two notable modifications in the treatment which require description.

The preparation of the sample for analysis is of great importance. It is preferable to reduce the sample to a fine powder by means of a large file, pass through a 100 mesh per inch sieve, grinding the material which does not pass through in a mill (a coffee mill answers admirably) until the whole of the sample has passed the sieve. It is then well mixed.

The acetone extraction is performed as usual, but is continued for two or three days, as the free sulphur present appears to be in an amorphous form and only passes into solution very slowly.

As the only organic filling agents in hard rubbers are resins and pitches, and never substitutes, the saponification test is omitted, while the extraction of resins and pitches becomes more important. To remove all the resins, acetone is decidedly unsatisfactory, and in many instances useless, as such substances as shellac (one of the chief organic non-rubber constituents of ebonite), and several other resins, are quite insoluble in acetone. They are, however, soluble in epichlorhydrin, and C. O. Weber suggests this as a solvent to be employed after the acetone extraction and before the pyridine extraction. Weber's method is as follows : The extractor and contents are taken direct from the acetone extraction, and, without drying, connected to a weighed flask containing about 75 cc. of epichlorhydrin (B.P. 117°C.). The flask is heated on a sand-bath or an asbestos board for three or four hours, removed, and the epichlorhydrin distilled off by heating in a paraffin-bath at 120°C. After wiping the outside of the flask with benzene until clean, it is dried for two hours at 110°C. The extract frequently contains sulphur in organic combination, the amount of which may readily be estimated in the same manner as the sulphur in the pyridine extract. In proceeding next to the extraction with pyridine, it is advisable first to dry the paper thimble and its contents, as pyridine and epichlorhydrin interact.

The extraction is then carried out as before. The sulphur in the residue left from the pyridine extraction is determined in the same manner as the "total sulphur in rubber," and represents the sulphur of vulcanisation *plus* the sulphur in the mineral matter. This latter is calculated

as below, and on deduction from the sulphur contained in the pyridine residue, gives the sulphur of vulcanisation.

The rubber is not determined by the nitronaphthalene extraction, but by difference from 100 per cent. The mineral matter is determined by incineration, and calculation from the bases found, all lead being calculated as litharge, antimony as pentasulphide, mercury as sulphide, magnesium as oxide, calcium as carbonate (or sulphate), zinc as oxide or sulphide, and barium as sulphate (rarely as carbonate).

To detect zinc sulphide a small amount of the original sample is warmed with hydrochloric acid. The evolution of hydrogen sulphide indicates the presence of zinc sulphide, carbon dioxide the presence of calcium or barium carbonate. In case the barium is insoluble, it will be present as the sulphate, not as the carbonate.

The quantity of sulphur required to form the necessary sulphides of zinc, antimony, or mercury is found by calculation from the amount of each base present, and is taken as the figure for " sulphur in the inorganic constituents," which is deducted from the amount of sulphur in the residue left from the pyridine extraction to obtain the amount of sulphur of vulcanisation.

As a further control for the figures for sulphur, an estimation of the total sulphur in the original sample may be performed.

As is the case with all indirect determinations, the estimation of rubber by difference is liable to several errors, but these are of little practical consequence in *normal* samples. Moreover, all suggestions of direct methods for the determination of india-rubber, such as the formation of polyprene tetrabromide, have been found quite useless in practice.

NOTES ON THE INTERPRETATION OF RESULTS.

Acetone extract : This important test is applied in practically every case, and is to be found embodied in the War Office specifications, as well as those of the leading railway and other companies.

The figures given by this test alone at once decide into which class to place the sample. The nature and quantity of the extract indicate immediately, although they do not exactly determine, the class of rubber used in the manufacture of the article under examination. In case the extract only contains rubber resins and free sulphur, it is usually of an oily or gummy nature, and may be washed from the crystals of sulphur with acetone, as previously described. The amount

of resin so obtained should then be calculated, in the first place on the total initial weight of the sample extracted, and also on the rubber proved subsequently to be present. This gives us a figure for "organic extract in india-rubber," and it is the restriction of this figure which is the object of the specifications relating to chemical tests on india-rubber. The War Office specifications for india-rubber will not accept a sample in which this figure exceeds 10 per cent., which excludes the use of medium and poor grade rubbers, as it is only such rubbers as Pará rubber, good plantation rubber, and especially good grades of Massai, and the like, which give so low a figure for the resin content. It may be claimed that Pará rubber only carries 3–4 per cent. of resin before manufacture, but it must be remembered that during mixing and vulcanisation the resin content of all rubbers increases; in some cases by as little as 2 per cent., in others by as much as 8 per cent. This discounts to a large extent the value of the conclusions drawn from this figure; on the other hand, it allows of general conclusions to be drawn on broad lines which may be of great assistance.

In case the extract contains resin oil, a characteristic blue fluorescence is noticeable in the extract, which will be of a dark colour. One of the best methods for detecting resin oil is Renard's reaction as given by Allen. The test reagent is stannic bromide, prepared by allowing bromine to fall drop by drop on granulated tin contained in a dry flask immersed in cold water. The addition is continued until the permanent coloration of the product shows that bromine is in excess. A further moderate addition of bromine is then made, and the liquid is diluted with three or four times its volume of carbon disulphide, in which the stannic bromide is readily soluble. To employ the reagent, which when thus prepared appears to be perfectly stable, a few drops of the sample to be tested should be placed in a dry test tube and dissolved in about 1 cc. of carbon disulphide. The bromide reagent is then gradually added, and if resin oil be present the liquid will rapidly acquire a fine violet coloration. In the presence of much mineral oil Allen finds it a good plan to first mix the sample of oil with a solution of stannic bromide in carbon disulphide, and then add, drop by drop, a solution of bromine in carbon disulphide, by which means a violet coloration is often to be obtained unobscured by any colour produced by the mineral oil. This colour is destroyed by the addition of alcohol, ether, ammonia, or water. Chloroform may be substituted for carbon disulphide in this test. Mineral oils impart a greenish fluorescence to the acetone solution during extraction, and may

be removed, together with all fatty oils (except castor oil) by washing out the other portions of the extract with alcohol, in which these oils are insoluble. By saponifying this oily residue, the fatty oils may be removed from the mineral oil. If no fatty substitutes be present the free oils in the extract must have been added to the mixing as such or in the form of reclaimed rubber (from which mineral oil can almost invariably be extracted).

If fatty substitutes be found, and the amount of free fatty oil does not exceed 15 per cent. of the amount of substitute present, it may be assumed that this oil is derived from the substitute, and has not been added as free oil to the mixing. Attention should be drawn to this point when presenting the report of analysis.

If such a sample is to be matched for manufacturing purposes, the substitute it is proposed to employ should be analysed, and any deficiency in free oil made up by addition of oil to the mixing. A substitute containing too much free oil must be discarded and replaced by one of lower oil content.

Any wax (paraffin wax or ozokerite) found in the extract may be estimated by warming with about 50 cc. glacial acetic acid, and allowing to cool, when the wax separates out. It is filtered off, washed with acetic acid, dissolved in carbon disulphide, evaporated to dryness in a weighed flask, and weighed.

Pyridine extract: Tar and pitch are often added to rubber mixings which contain low grade rubbers, or mixings carrying large amounts of " dry " matter, such as ground waste rubber or an excessive amount of mineral matter, with the object of facilitating the operation of mixing. They also reduce the porosity of the resultant goods and render them more inert to the influences of air, light, and chemical action. The use of asphaltum is confined to hard rubber goods. Although scarcely a point of chemical interest, it is still worthy of note that the majority of rubber goods received from America contain reclaimed rubber and " mineral rubber " (a black flexible tough substance partaking of the nature of both the waxes and the bitumens), while European samples often contain less of these ingredients and more fatty substitutes.

Alcoholic potash extract: The fatty substitutes saponified by this process may be oxidised oils, or chloro-sulphide substitutes in cold vulcanised goods, or sulphide substitutes with or without the other two in hot vulcanised goods. Sulphide substitutes are never used in cold vulcanised articles, and as cold vulcanisation by means of a 2 per cent. solution of sulphur monochloride in carbon disulphide can only be applied

to thin articles, any such goods which give a test which indicates the presence of sulphide substitutes must be regarded with suspicion. A more frequent error is the misrepresentation of the chloro-sulphide substitute present in hot vulcanised goods as sulphide substitute. This is due to the fact that during the process of vulcanisation the chlorine in this substitute is to a large extent evolved as hydrochloric acid, which is absorbed both by the mineral matter and the india-rubber, leaving the alcoholic potash extract almost free from chlorine. The chlorine will be found in the india-rubber, and may give rise to the impression that the goods have been " cold cured." That this is erroneous becomes obvious when the thickness of the goods is taken into consideration, for it is manifestly impossible to vulcanise valves, cab tyres, hose, or buffers, by cold vulcanisation. It must also be remembered that sulphide substitutes are *never* used in " cold cured " articles.

Nitronaphthalene extract: By this means the amount of vulcanised rubber contained in the sample is estimated. This sample includes the new rubber, together with any reclaimed rubber, waste rubber, and balata which may have been added.

Since the rubber (of whatever kind) or balata is only present in the extract in the form of its decomposition products, it is impossible as yet to determine chemically which kind of rubber was originally employed, and no chemical means of detecting reclaimed rubber or balata have hitherto been devised. The presence of ground rubber waste may often be detected microscopically by examining the original sample under a ¼ " objective, when a peculiar granular structure is revealed This method is, however, not quantitative.

On calculating the " sulphur of vulcanisation " on the " india-rubber " present, a figure known as the " coefficient of vulcanisation " is obtained. Thus, a sample containing 60 per cent. of " india-rubber," and 3 per cent. of " sulphur of vulcanisation " would show a " coefficient of vulcanisation " of 5 per cent. With a mixing containing a definite quantity of new rubber, the higher the coefficient of vulcanisation, the harder will be the final article. If, however, a high coefficient of vulcanisation be found where the physical condition of the goods suggests a lower coefficient, then the presence of reclaimed rubber must be strongly suspected, since reclaimed rubbers, although softened by reclaiming, still contain their full quantity of combined sulphur, which thus increases the final " coefficient of vulcanisation." The presence of reclaimed rubber is further indicated by a high figure for " organic extract" in india-rubber (see *acetone extract*). In cases where

reclaimed rubber is present, mineral or resin oils are always found in the acetone extract.

Water extract : The presence of such organic fillers as starches is of such rare occurrence that this extraction is usually omitted, although it was of some importance before the introduction of the fatty substitutes.

Inorganic constituents : Although the detection and determination of these constituents offer little difficulty, it is often useful to know what minerals to expect in any particular grade of rubber. In " heat-resisting " rubbers, such as steam rubbers and jointings, litharge is nearly always present, as is also asbestos, talc, and often magnesia or lime. The majority of rubber mixings for mechanical goods contain zinc as oxide or sulphide, barium sulphate, and calcium carbonate. Rubber goods intended to withstand the action of acids do not contain carbonates or oxides (with the exception of litharge), and are usually filled with substitutes, mineral rubber, wax, and the silicates such as french chalk, asbestos, atmoid, together with barytes. The action of litharge and magnesium oxide being to accelerate vulcanisation and produce a harder and tougher product, they are often found in cab tyres and other articles which are called upon to withstand mechanical abrasion.

In case traces of almost every mineral used by the manufacturer be found in a sample the presence of reclaimed or ground waste rubber should at once be suspected, since it is by those channels that many constituents occur in rubber goods entirely without the knowledge of the manufacturer.

ANALYSIS OF TOBACCO.

S. E. HODGKINSON, B.Com., F.I.C.

BRITISH TOBACCO EXCISE REGULATION.

Tobacco is neither a food nor a drug, so its purity is not guarded by the Food and Drugs Act. It is, however, a very important source of revenue to the State, and very stringent regulations as to its purity and manufacture are stipulated by the Commissioners of Customs and Excise. It must not contain more than 32 per cent. of water nor more than 4 per cent. of oil. Further, it must not contain any ingredients other than tobacco, water, oil, essential oils (for flavouring), or acetic acid.

TECHNICAL ASSAY OF TOBACCO.

Chemical analysis of tobacco is not of much assistance in arriving at a decision as to its quality, and as a consequence the only estimations usually made are those for water, oil, nicotine, inorganic matter and sand, which, other than nicotine, are required for legal purposes. For plant purposes the nicotine determination is the only one required; and Garner's method is to be recommended instead of the more accurate but lengthy A.O.A.C. official methods.

Water.

A known weight is dried at 100°C. for eight hours. Other substances than water are vaporised, but, from the wording of the moisture clause of the Revenue Act, these must be calculated as water.

Oil.

13·33 grm. of the tobacco, very finely divided, are macerated for twelve hours with 100 cc. of petroleum ether; 75 cc. (representing 10 grms. of tobacco) of the ethereal extract are drawn off, filtered if necessary, and placed in a tared flask. The ether is distilled off, and the residual extract dried at 100°C. for one hour and weighed. If the total extract is below 4·5 per cent., it may be assumed that the amount of oil is below 4 per cent. For this method to be considered accurate a determination of the amount of extractable matter in the leaf from which the tobacco was

manufactured would have to be made. Amounts varying from 2·9 to 4·5 per cent. of extractable matter have recently been obtained in two varieties of leaf as imported. Such values are, however, exceptional, the usual amount obtained from raw leaf being about 0·5 per cent. By the present method of analysis, manufactured tobacco sometimes gives a lower ether extract than the leaf from which it is made. A comparison of the saponification value of the ether extract with that of the oil used assists in obtaining an idea of the amount of added oil.

Inorganic Matter and Sand.

The tobacco is first dried, and a definite weight incinerated over a small Bunsen flame. After all the "volatile carbon" has been expelled the incineration is completed in a muffle furnace at a dull red heat, cooled, and the ash moistened with a strong solution of ammonium carbonate, in order to recarbonate the free bases. It is then dried for eighteen hours and weighed.

Sand.

The ash obtained as above is treated with hydrochloric acid (1 : 6) filtered, the residue dried, ignited and weighed. Another method is to treat the ash with concentrated hydrochloric acid, evaporate to dryness, heat to 150°C. for half an hour, treat with dilute hydrochloric acid (1 : 12), filter, dry the residue, ignite and weigh.

Nicotine.

Many methods have been proposed for the estimation of nicotine, of varying degrees of reliability. (For a comparative study of six methods see J. Tóth, *J.S.C.I.*, 1911, 1084.) Three methods are here described. (For other methods see Kissling, *Analyst*, 1904, 378; Bertrand and Javillier, *J.S.C.I.*, 1899, 404, *J.S.C.I.*, 1909, 326, *J.S.C.I.* 1911, 978; J. Tóth, *Analyst*, 1912, 452; Schröder, *Analyst*, 1911, 106; Harrison and Self, *Pharm.* J., 1912, 718; *J.C.S.*, 1922, ii, 404); Heidnschka and Wolff, *J.C.S.*, 1920, ii., 780; and Kolthoff, *J.C.S.*, 1920, ii., 781).

The following method is due to Garner (Bulletin No. 102 U.S. Bureau of Plant Industry, Washington, 1907). It appears to be a modification of one by Schloesing (described in Grandeau's Agricultural Chemical Analysis, Berlin, 1879). It is rapid and sufficiently accurate for technical purposes.

6 grm. of finely divided air-dried tobaccos are well mixed with 3 to 5 cc. of a 5 per cent. solution of caustic soda and transferred to a 250 cc. stoppered cylinder. Or the tobacco

may be mixed in the cylinder by means of a long glass rod. 100 cc. of petroleum ether are added, and vigorously shaken. The mixture is allowed to stand for four hours, the cylinder being laid on its side so as to expose a greater surface of tobacco to the action of the ether, shaking vigorously every 30 mins. After allowing the mixture to settle the clear extract is passed through a filter, 75 cc. of the filtrate, equal to 4·5 grm. tobacco being collected. This is allowed to stand in an open flask exposed to the air, for $\frac{1}{2}$ hr., or air is drawn through it, to remove the ammonia, only a small proportion of which is extracted by the ether. It is next shaken in a separating funnel with 10 cc. N/5 sulphuric acid diluted to 50 cc. with water. The aqueous layer is drawn off, the petroleum spirit washed twice with a little water, and the excess of acid in the aqueous liquid titrated with N/10 alkali, using cochineal as indicator. 1 cc. N/5 acid is equal to 0·0324 grm. nicotine. The amount of water is determined in a corresponding sample, and the weight of tobacco taken corrected accordingly. The main difference of the above from Töth's method is that Töth recommends moistening the tobacco and mixing with plaster of Paris until the whole forms a dry powdery mass, the plaster of Paris retaining the ammonia. Toluene or xylene may be used as solvent.

The standard methods of the A.O.A.C. are the Kissling Method and the Silicotungstic Acid Method, described below.

Kissling's Method for the determination of Nicotine.

Weigh about 20 grm. of finely-powdered tobacco, which has been previously dried at 60°C. Add 10 cc. of alcoholic soda solution (6 grm. caustic soda, 40 cc. water and 60 cc. 90 per cent. alcohol) and mix thoroughly. Transfer to a Soxhlet extractor and exhaust for five hours with ether. Evaporate off the ether at a low temperature, and take up the residue with 50 cc. dilute caustic soda solution (4 grm. caustic soda in 1000 cc. of water). Transfer this residue by means of water to a Kjeldahl distillation apparatus, capable of holding about 500 cc., and distil in a current of steam, using a well-cooled condenser. A few pieces of pumice and a small piece of paraffin should be used to prevent bumping and frothing. Continue the distillation until all the nicotine has passed over, the distillate usually varying from 400 cc. to 500 cc. When the distillation is complete only about 15 cc. of the liquid should remain in the distillation flask. Titrate the distillate with N/10 sulphuric acid, using phenacetolin or cochineal as indicator. One molecule of sulphuric acid is equivalent to two molecules of nicotine.

Silicotungstic Acid Method for the determination of Nicotine.

Silicotungstic acid solution. Prepare a 12 per cent. solution of the silicotungstic acid having the following formula: $4H_2O.SiO_2.12WO_3.22H_2O$.

Sodium or potassium hydroxide solution (1 : 2), and dilute hydrochloric acid (1 : 4), are also necessary.

Weigh such an amount of the preparation as will contain preferably between 0·1 and 1·0 grm. of nicotine (if the sample contains very little nicotine, about 0·1 per cent., do not increase the amount to the point where it interferes with the distillation); wash with water into a 500 cc. round-bottomed distillation flask; add a small amount of paraffin to prevent frothing, a few small pieces of pumice and a slight excess of the sodium or potassium hydroxide, using phenolphthalein as an indicator. Steam distil rapidly through an efficient condenser connected, by means of an adapter, with a suitable flask containing 10 cc. of the dilute hydrochloric acid. When distillation is proceeding, heat the distillation flask to reduce the volume of the liquid as far as practicable without bumping or undue separation of insoluble matter. Distil until a few cc. of the distillate show no opalescence when treated with a drop of the silicotungstic acid and a drop of the dilute hydrochloric acid. Confirm the alkalinity of the residue in the distillation flask with phenolphthalein solution. Make up the distillate, which may amount to 1000—1500 cc. to a convenient volume (the solution may be concentrated on the steam-bath without loss of nicotine), mix well, and, if not clear, pass through a large dry filter. Test a portion with methyl orange to ensure its acidity. Pipette an aliquot portion, containing about 0·1 grm. of nicotine into a beaker (if the samples contain very small amounts of nicotine, an aliquot containing as little as 0·01 grm. of nicotine may be used), and add to each 100 cc. of liquid 3 cc. of the dilute hydrochloric acid, or more if the necessity is indicated by the test with methyl orange, and 1 cc. of the silicotungstic acid for each 0·01 grm. of nicotine supposed to be present. Stir thoroughly and allow to stand overnight. Before filtering, stir the precipitate to see that it settles quickly and is in crystalline form; then filter on an ashless filter, and wash with cold dilute hydrochloric acid (1 : 1000). Transfer the paper and precipitate to a weighed platinum crucible, dry carefully, and ignite until all carbon is removed. Finally, heat over a Téclu or Méker burner for not more than 10 mins. The weight of the residue, multiplied by 0·114, gives the weight of nicotine present in the aliquot portion.

Percentage Composition of American Tobacco
Dried at 100°C.   (G. E. Moore).

	Virginia Sun-cured	Virginia Flue-cured low grade	Clarkesville Fire-cured Soil: heavy rich loam	Kentucky Air-cured	Perique	Wisconsin Seed leaf
	1	2	3	4	5	6
Nicotine	3.26	4.30	5.29	3.12	4.32	0.86
Resin and fats	4.15	4.65	4.99	5.34	6.28	3.28
Starch	5.89	2.75	3.54	4.46	2.45	4.15
Glucose	6.89	2.75	0.00	0.00	0.00	0.00
Albuminoids (N. ×6.25) ..	16.09	13.66	16.54	15.98	15.80	20.34
Pectic (acid anhydride)	6.19	7.46	6.01	7.49	6.66	11.61
Citric ,, ...	2.12	2.84	2.99	4.05	1.18	2.99
Malic ,, ...	5.02	7.58	5.51	9.26	3.94	6.88
Oxalic , ...	0.84	1.03	1.30	2.18	3.49	1.07
Acetic ,, ...	0.42	0.55	0.39	0.64	1.62	0.68
Nitric ,, ...	0.00	0.00	1.55	0.00	0.00	1.22
Ammonia	0.33	0.32	0.98	0.48	0.76	0.63
Crude fibre	9.58	9.24	9.68	12.18	9.08	12.97
Sand	0.55	2.38	2.25	0.66	4.17	1.53
Ash (exclusive of sand and CO_2)	12.41	13.36	14.37	16.06	13.30	15.43
Undetermined	26.26	27.13	24.61	18.11	26.95	16.36

ASH ANALYSES.

	Virginia Sun-cured	Virginia Flue-cured low grade	Clarkesville Fire-cured Soil: heavy rich loam	Kentucky Air-cured	Wisconsin Seed leaf
Total Ash	14.29	17.42	19.23	21.85	20.81
Ash (exclusive of sand and CO_2)	12.41	13.36	14.37	16.06	15.43
Potash	34.16	26.55	33.15	39.51	38.71
Soda	0.26	0.22	0.15	0.86	1.08
Lime	31.76	36.96	36.48	39.80	33.49
Magnesia	7.91	11.51	11.85	5.34	12.57
Ferric oxide	0.58	0.95	0.51	1.56	0.79
Alumina	1.22	1.81	0.95	0.51	0.74
Manganous oxide	0.00	0.00	0.25	0.13	trace
Phosphoric anhydride ..	3.81	3.23	4.42	6.09	3.09
Sulphuric ,, ..	4.99	4.27	6.16	4.52	3.89
Silicic ,, ..	1.39	3.29	3.42	1.20	4.65
Chlorine	13.92	11.21	2.66	0.48	0.99

J 2

CHEMICAL INVENTIONS AND THE LAW OF PATENTS.

H. E. Potts, M.Sc., Chartered Patent Agent.

In order to obtain the best results from the patent system, it is desirable that chemists should become familiar with some of the leading features of patent law. All that can be done here is to indicate some of the chief points of interest, and to explain why the chemist should give them his attention.

1. *Patents or Secret Processes.*

Many chemists do not realise that processes can be protected, and that infringement can be prevented, even though competitors might try to use the process unlawfully. Apart from the possibility of leakage of information, it is possible in appropriate cases to obtain an order for inspection of the defendant's works by independent experts, or the Court may order the defendant to answer questions termed "interrogatories." Infringement actions have been successful where the defendants used the patented process abroad, or alleged that they had a process of their own which was so secret that the Court heard the evidence *in camera*.

The objection that infringers will escape by making some slight modification of the patented process is based on an erroneous conception of the scope of a patent, which, if skilfully drafted, prevents such modifications.

Secret working suffers from the grave dangers that the monopoly is entirely lost if the secret leaks out, and that others may independently discover the secret, and even patent it. This will entail loss of foreign rights, and may cause serious inconvenience in the United Kingdom. In fact, if one firm has developed a process but not used it *commercially*, another party may well obtain a valid patent preventing the first firm from proceeding further.

The research chemist will find that patents are more negotiable than secret processes, and once a process has been patented, publication of his research work can be made safely, with advantage to his professional standing.

Secret working is most likely to be of value for inventions dealing with foods or medicines which may be difficult to patent.

2. *What can be patented?*

It is best for the chemist to forget preconceived ideas, and to accept the dogmatic statement that, in effect, the majority of new and useful improvements are patentable. The Patent Office will grant a patent for any new variation of an existing process, and *a fortiori*, for any new process; if such a variation or process is not obvious, and possesses substantial advantages in practice, the Court would probably hold the patent valid. Thus patents can be obtained—

- (a) to protect a new reaction broadly, as applied to a useful purpose;
- (b) to protect combinations of known steps giving a new result, *e.g.*, lustring cotton by combining the old steps of treatment with caustic soda and stretching;
- (c) to protect variations in detail in an existing process, *e.g.*, the discovery that mercerisation can be effected with advantage at some particular concentration of caustic soda, although the literature contains general statements as to ranges of concentration including the new concentration;
- (d) to protect the application of a known process to homologues if the result could not have been definitely foreseen; thus a dyestuff patent may cover the extension of an existing process to alkyl derivatives of a known intermediate.

In all these cases, a specific improvement is not anticipated by mere vague statements in the literature which would not lead a skilled chemist to the desired result unless he had been taught by the patentee. Mere analogy is not conclusive ground of anticipation in chemical patents. If it is discovered that a certain catalyst gives good results in the reduction of phenol to cyclo-hexanol, it would not be legitimate to argue that this was not patentable merely because—

- (i) it was known that phenol could be reduced catalytically to cyclo-hexanol; and
- (ii) it was known that the particular catalyst could be used for other reactions.

Catalytic phenomena are so specific and difficult to predict that a patent would certainly be allowed if the particular catalyst had never been used *for this reaction*, and if the results were favourable, the Court would probably sustain the patent.

A novel improvement can be patented, even though it infringes an existing patent. Infringement and anticipation are different issues.

3. *Requirements as to inventorship.*

The original inventor must appear as one of the applicants for a British patent (unless it is filed as a communication from abroad or under the International Convention) : other names, including the name of a firm, may be added. The law as to the rights of joint applicants is complex, and it is advisable for both chemist and employer that their respective rights should be defined by an equitable agreement.

A patent application must be filed before the invention has been "published" : the term publication includes oral communication to parties not under the bond of secrecy. The application ought to be made if possible before the invention is used commercially, *i.e.*, in the works as distinct from the laboratory. Indeed, it is desirable to obtain provisional protection at the earliest possible date to avoid risk of leakage or independent invention by competitors.

4. *Patent applications.*

Although a complete specification may be filed in the first instance, it is nearly always advisable to file a provisional specification, because this procedure gives a period of nine months' protection in which the invention can be further developed.

The provisional specification ought to describe the invention as fully as possible, but it need not be as detailed as a complete specification, and it can contain a forecast of future work,—to be elaborated in detail before the complete specification is filed.

In preparing a provisional specification, care should be taken to forestall possible evasions by competitors, and the protection should not be limited to a mere recital of optimum conditions, although if the specification is correctly drafted it is advisable to give optimum conditions without limiting protection to those conditions only.

It is often unwise to delay filing a provisional specification until the process has been successful on a large scale, or until commercial possibilities are favourable. If the nine months is not sufficient to develop the invention, the provisional specification can be abandoned, and in this case it is *not* published, so that a fresh provisional specification can be filed giving a further nine months' protection, but with the loss of the original priority ; or the matter can then be kept entirely secret.

During the period of provisional protection, in addition to the work required to convert a laboratory process into a

large scale process, it is also desirable to develop the theory of the process, and to investigate possible variations, such as those foreshadowed in the provisional specification. Care should also be taken to verify all experimental data, and to give examples of the process which will be sufficient to enable a skilled chemist to obtain some beneficial result.

There should be a full and frank discussion between chemist and patent agent at all stages in the prosecution of the application.

After the complete specification has been filed, the Patent Office issues a report which gives the results of the official search, and draws attention to any points as to which amendment may be necessary. The cited publications and these objections must be carefully considered; the specification must be amended, or suitable arguments must be filed to overcome the official objections. This action on the part of the Patent Office usually strengthens the patent, if adequate attention is given to the preparation of a reply—which should not usually consist in a mere cancellation of the passages to which objection is raised, or a mere statement that the examiner's objections are irrelevant.

5. *Scope of patents.*

While a single important patent occasionally dominates an entire field of industry, it usually happens that the original patentees buttress their position by subsidiary patents, which will assist in extending the practical monopoly beyond the life of the original patent. It is important to obtain protection for possible modifications of the original process as they are discovered, because although these modifications may not be superior in any way, the patents will deter competitors by blocking research in parallel directions.

On the other hand, if the competitor himself has patents it must not be hastily assumed that his position is impregnable. The patents may be invalid, or it may be possible to devise efficient modifications which will not infringe. The field covered by the patents should therefore be thoroughly surveyed, in the light of a full knowledge of the relevant literature, to ascertain whether there are any loopholes, and if so, research should then be pursued along the lines indicated by this survey.

6. *Products.*

It is now difficult to obtain patents for inventions dealing with foods or medicines, unless there is a " special " process of manufacture. Mere mixing is not usually considered

"special," and in the opinion of the writer there is now, in practice, a higher standard of patentability for these inventions than for those relating to mechanism.

7. *Patents abroad.*

Important chemical inventions are usually protected in France, Germany and U.S.A. if possible, although other countries are often important. The British patent does not cover the Empire, and a Canadian patent is often desirable if the invention is to be worked in U.S.A.

In Germany, the Patent Office makes a very thorough search for novelty among the scientific literature and patent specifications of the world. The examiners reject a patent if they consider the process is obvious to the skilled chemist. It is therefore necessary to bring forward any arguments which show that the result obtained by the invention is contrary to expectation, or that the result is characteristic in some striking way; arguments of a theoretical nature are often successful, but sometimes reports by acknowledged expert chemists are helpful.

The German law allows patents for chemical processes, but not for purely chemical products, although these are protected by the patent if made by the patented process. Entirely different methods of making the new product are not protected (*cf.* Section 38A of the British Act).

In U.S.A. the examination for novelty is fairly extensive, but the standard is not usually so rigid as in Germany. The broadest claims can be obtained for chemical products as such, however prepared, and claims are even allowed for known substances of a certain high degree of purity as shown by a M.P. higher than that ever recorded previously. The preparation of claims is governed by a highly elaborate and artificial system of rules which cannot be briefly summarized.

8. *Literature.*

Fuller information will be found in the standard text-books on Patent Law by Frost, Fletcher Moulton and Terrell. See also " Patents and Chemical Research " (Potts). Current decisions are given in the " Reports of Patent Cases."

NOTABLE DATES IN THE HISTORY OF CHEMISTRY.

	B.C
Thales. Water, the Element of the World.	640–550
Pythagoras. Mass.	582–500
Anaximenes. Air, the World Principle.	*circa* 550
Empedocles. Four principles : Fire, water, air, earth.	492–432
Hippocrates. Recognised and employed 230 species of plants as medicines.	460–377
Democritus, creator, with Leucippus, of the Atomic theory.	460–370
Theophrastos. Recognised 500 plants. Mineralogy. Prepared white lead and litharge.	390–286
Aristoteles. Matter, form and motion.	384–322
Archimedes. Principle of the lever ; hydrostatics.	287–212

	A.D.
Dioskorides, recognised 600 herbs, wrote "De materia medica,"	50
Caius Plinius Secundus. Author of "Historia naturalis,"	79
Zosimos of Panopolis (Egypt) used the word $\chi\eta\mu\iota\alpha$ or $\chi\eta\mu\epsilon\iota\alpha$ to indicate the art of making gold and silver about	250
Djafar or *Geber.* Discovered aqua fortis, aqua regia, lapis infernalis, and sublimate ; also the processes of distillation, cupellation etc.	702–765
Rhases. Recognised vitriol, alcohol. Born in	932
Avicenna. Medicinal and mineralogical papers. (Rocks, metals, sulphur compounds and salts.)	980–1037
Albertus Magnus. Founder of Alchemy.	1193–1280
Roger Bacon. Methods of research in natural science ; mirrors, magnifying glass ; doubted transmutation of metals.	1214–1294
Raymundus Lullius. Prepared nitric acid, "aqua prima."	1235–1315
Basil Valentine. Antimony salts. Prepared hydrochloric acid, "currus triumphalis antimonii,"	1413
Eck noted increase in weight of metals on calcination, and oxygen ; "Theatrum chymicum,"	1489
Georg Agricola. Mineralogy and metallurgy, "De re metallica libri xii."	1490–1555
Paracelsus. Iatrochemistry, application of chemistry to medicines.	1493–1541
Leonardo da Vinci, noted artist, published his "Codex Atlanticus," containing a correct view of combustion,	*circa* 1500

Réaumur (1693–1757) suggested scale for thermometry,	1730
Linné (1707–1778) founded his botanical system in "Systema naturæ,"	1735
Celsius (1701–1744) suggested scale for thermometry, known in England as Centigrade,	1740
Brandt (1694–1768) isolated cobalt,	1743
Zinc manufactured on a large scale at Bristol,	1743
Roebuck erected first lead chamber for sulphuric acid manufacture at Preston Pans,	1746
Marggraff (1709–1783) discovered sugar in beetroot,	1747
Antonio de Ulloa (1716–1795) described platinum in "Relacion de viage a la America meridional,"	1748
Cronstedt (1702–1756) isolated nickel,	1751
Black (1728–1799) stated the difference between caustic and carbonated alkalies, investigated specific heat of water, etc.,	1755
Watt (1736–1819) invented the steam engine,	1769
Priestley (1733–1804) discovered oxygen and ammonia,	1774
Scheele (1742–1786) discovered chlorine ("dephlogistigated marine acid gas"),	1774
Scheele discovered oxygen, 1773, published discovery,	1775
Lavoisier (1743–1794) found composition of air ("oxygène"); theory of combustion,	1775
Gahn (1745–1818) isolated manganese,	1775
Bergmann (1735–1784) decomposed oxalic acid into carbon dioxide and carbon monoxide,	1775
Scheele discovered glycerin,	1779
Scheele discovered hydrocyanic acid,	1782
Hjelm (1746–1813) isolated molybdenum,	1782
Fausto d'Elhuyar (1755–1832) discovered tungsten,	1783
Cavendish (1731–1810) discovered hydrogen; synthesised water,	1784
Cort used puddling process in manufacture of iron,	1784
Klaproth (1743–1817) discovered uranium and the zirconium earths,	1789
Berthollet (1748–1822) introduced bleaching powder,	1789
Leblanc discovered method for manufacture of soda (details first published in 1797),	1791
Richter (1762–1807) stated law of definite proportions in "Anfangsgründe der Stöchiometrie,"	1792
Klaproth discovered titanium,	1795
Berzelius discovered zirconium,	1795
Lampadius (1772–1842) discovered carbon disulphide,	1796
Vauquelin (1763–1829) discovered chromium,	1797
Klaproth discovered tellurium,	**1798**

CHEMICAL AND OTHER SCIENTIFIC JOURNALS.

J.Amer. C.S.	Gazz. ch.it.	Dingl. polyt.	Compt. rend.	Chem. Zentr.	Chem. Ztg.	Chem. News	Chem. Gaz.	Bull. S.chim.	Ber.	Ann. Min.	Analyst.	J.Sci. Amer.	Amer. C.J.	Ann. chim.	Ann. Suppl.	Ann. (Lieb.)	Year.
		115-118	30, 31	21			7			17, 18		9, 10		28-30		73-76	1850
		119-122	32, 33	22			8			19, 20		11, 12		31-33		77-80	1851
		123-126	34, 35	23			9			(5) 1,2		13, 14		34-36		81-84	1852
		127-130	36, 37	24			10			3, 4		15, 16		37-39		85-88	1853
		131-134	38, 39	25			11			5, 6		17, 18		40-42		89-92	1854
		135-138	40, 41	26			12			7, 8		19, 20		43-45		93-96	1855
		139-142	42, 43	27			13			9, 10		21, 22		46-48		97-100	1856
		143-146	44, 45	28			14			11, 12		23, 24		49-51	1	101-104	1857
		147-150	46, 47	29			15	1		13, 14		25, 26		52-54	2	105-108	1858
		151-154	48, 49	30			16	2		15, 16		27, 28		55-57		109-112	1859
		155-158	50, 51	31		1, 2	17	3		17, 18		29, 30		58-60	3	113-116	1860
		159-162	52, 53	32		3, 4	Ctd. as ↑	4		19, 20		31, 32		61-63	4	117-120	1861
		163-166	54, 55	33		5, 6		5		(6) 1,2		33, 34		64-66	5	121-124	1862
		167-170	56, 57	34		7, 8				3, 4		35, 36		67-69	6	125-128	1863
		171-174	58, 59	35		9, 10		(2) 1,2		5, 6		37, 38		(4) 1-3		129-132	1864
		175-178	60, 61	36		11, 12		3, 4		7, 8		39, 40		4-6	7	133-136	1865
		179-182	62, 63	37		13, 14		5, 6		9, 10		41, 42		7-9		137-140	1866
		183-186	64, 65	38		15, 16		7, 8		11, 12		43, 44		10-12	8	141-144	1867
		187-190	66, 67	39		17, 18		9, 10	1	13, 14		45, 46		13-15		145-148	1868
		191-194	68, 69	40		19, 20		11, 12	2	15, 16		47, 48		16-18		149-152	1869
		195-198	70, 71	41		21, 22		13, 14	3	17, 18		49, 50		19-21		153-156	1870
	1	199-202	72, 73	42		23, 24		15, 16	4	19, 20		(3) 1,2		22-24		157-160	1871
	2	203-206	74, 75	43		25, 26		17, 18	5	(7) 1,2		3, 4		25-27		161-164	1872
	3	207-210	76, 77	44		27, 28		19, 20	6	3, 4		5, 6		28-30		165-168	1873
	4	211-214	78, 79	45		29, 30		21, 22	7	5, 6		7, 8		(5) 1-3		169-172	1874
	5	215-218	80, 81	46		31, 32		23, 24	8	7, 8		9, 10		4-6		173-176	1875
	6	219-222	82, 83	47		33, 34		25, 26	9	9, 10	1	11, 12		7-9		177-179	1876
	7	223-226	84, 85	48	1	35, 36		27, 28	10	11, 12	2	13, 14		10-12		180-183	1877
	8	227-230	86, 87	49	2	37, 38		29, 30	11	13, 14	3	15, 16		13-15		184-189	1878
1	9	231-234	88, 89	50	3	39, 40		31, 32	12	15, 16	4	17, 18	1	16-18		190-194	1879
2	10	235-238	90, 91	51	4	41, 42		33, 34	13	17, 18	5	19, 20	2	19-21		195-199	1880

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	4, 5		140	36, 37					49-51	3	1850
	6, 7	5	141	(4) 1, 2					52-54	4	1851
	8, 9		142	3, 4					55-57	5	1852
	10, 11	6	143	5, 6					58-60	6	1853
	12-14		144	7, 8					61-63	7	1854
	15-18	7	145	9, 10					64-66	8	1855
	19-21	8	146	11, 12					67-69	9	1856
	22-27		147	13, 14					70-72	10	1857
	28-33	9	148	15, 16					73-75	11	1858
	34-38	10	149	17, 18		(1) 1			76-78	12	1859
	39-42	11	150	19, 20		2			79-81	13	1860
	43	12	151	21, 22		3			82-84	14	1861
1	44, 45	13	152	23, 24		4			85-87	15	1862
2	46-48	14	153	25, 26		(2) 5			88-90	16	1863
3	49		154	27, 28		6			91-93	17	1864
4	50-52	15	155	29, 30		7			94-96	18	1865
5	53, 54	16	156	31, 32		8			97-99	19	1866
6	55, 56	17	157	33, 34		9			100-102	20	1867
7	57, 58	18	158	35, 36		10			103-105	21	1868
8	59, 60	19	159	37, 38		11		1	106-108	22	1869
9	61, 62	20	160	39, 40	1, 2	12		2	(2) 1, 2	23	1870
10	63, 64	21	161	41, 42	3, 4	(3) 13		3	3, 4	24	1871
11	65, 66	22	162	43, 44	5, 6	14		4	5, 6	25	1872
12	67, 68	23	163	45, 46	7, 8	15		5	7, 8	26	1873
13	69, 70	24	164	47, 48	9, 10	16		6	9, 10	27	1874
14	71, 72	25, 26	165	49, 50	11, 12	17		7	11, 12	28	1875
15	73, 74	27	166	(5) 1, 2	13, 14	18		8	13, 14	29, 30	1876
16	75, 76	28, 29	167	3, 4	15, 16	19		9	15, 16	31, 32	1877
17	77, 78	30	168	5, 6	17, 18	20		10	17, 18	33, 34	1878
18	79, 80		169	7, 8	19, 20	21		11	19, 20	35, 36	1879
19	81, 82		170, 171	9, 10	21, 22	22		12	21, 22	37, 38	1880

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3	11	239-242	92, 93	52	5	43, 44	35, 36	14	19, 20	6	21, 22	3	22-24	206-210	1881
4	12	243-246	94, 95	53	6	45, 46	37, 38	15	(8) 1, 2	7	23, 24	4	25-27	211-215	1882
5	13	247-250	96, 97	54	7	47, 48	39, 40	16	3, 4	8	25, 26	5	28-30	216-221	1883
6	14	251-254	98, 99	55	8	49, 50	41, 42	17	5, 6	9	27, 28	6	(6) 1-3	222-226	1884
7	15	255-258	100, 101	56	9	51, 52	43, 44	18	7, 8	10	29, 30	7	4-6	227-231	1885
8	16	259-262	102, 103	57	10	53, 54	45, 46	19	9, 10	11	31, 32	8	7-9	232-236	1886
9	17	263-266	104, 105	58	11	55, 56	47, 48	20	11, 12	12	33, 34	9	10-12	237-242	1887
10	18	267-270	106, 107	59	12	57, 58	49, 50	21	13, 14	13	35, 36	10	13-15	243-249	1888
11	19	271-274	108, 109	60	13	59, 60	(3) 1, 2	22	15, 16	14	37, 38	11	16-18	250-255	1889
12	20	275-278	110, 111	61	14	61, 62	3, 4	23	17, 18	15	39, 40	12	19-21	256-260	1890
13	21	279-282	112, 113	62	15	63, 64	5, 6	24	19, 20	16	41, 42	13	22-24	261-266	1891
14	22	283-286	114, 115	63	16	65, 66	7, 8	25	(9) 1, 2	17	43, 44	14	25-27	266-271	1892
15	23	287-290	116, 117	64	17	67, 68	9, 10	26	3, 4	18	45, 46	15	28-30	272-277	1893
16	24	291-294	118, 119	65	18	69, 70	11, 12	27	5, 6	19	47, 48	16	(7) 1-3	278-283	1894
17	25	295-298	120, 121	66	19	71, 72	13, 14	28	7, 8	20	49, 50	17	4-6	284-288	1895
18	26	299-302	122, 123	67	20	73, 74	15, 16	29	9, 10	21	(4) 1, 2	18	7-9	289-293	1896
19	27	303-306	124, 125	68	21	75, 76	17, 18	30	11, 12	22	3, 4	19	10-12	294-298	1897
20	28	307-310	126, 127	69	22	77, 78	19, 20	31	13, 14	23	5, 6	20	13-15	299-303	1898
21	29	311-314	128, 129	70	23	79, 80	21, 22	32	15, 16	24	7, 8	21, 22	16-18	304-309	1899
22	30	315	130, 131	71	24	81, 82	23, 24	33	17, 18	25	9, 10	23, 24	19-21	310-313	1900
23	31	316	132, 133	72	25	83, 84	25, 26	34	19, 20	26	11, 12	25, 26	22-24	314-319	1901
24	32	317	134, 135	73	26	85, 86	27, 28	35	(10) 1, 2	27	13, 14	27, 28	25-27	320-325	1902
25	33	318	136, 137	74	27	87, 88	29, 30	36	3, 4	28	15, 16	29, 30	28-30	326-329	1903
26	34	319	138, 139	75	28	89, 90	31, 32	37	5, 6	29	17, 18	31, 32	(8) 1-3	330-337	1904
27	35	320	140, 141	76	29	91, 92	33, 34	38	7, 8	30	19, 20	33, 34	4-6	338-343	1905
28	36	321	142, 143	77	30	93, 94	35, 36	39	9, 10	31	21, 22	35, 36	7-9	344-350	1906
29	37	322	144, 145	78	31	95, 96	(4) 1, 2	40	11, 12	32	23, 24	37, 38	10-12	351-357	1907
30	38	323	146, 147	79	32	97, 98	3, 4	41	13, 14	33	25, 26	39, 40	13-15	358-363	1908
31	39	324	148, 149	80	33	99, 100	5, 6	42	15, 16	34	27, 28	41, 42	16-18	364-371	1909
32	40	325	150, 151	81	34	101, 102	7, 8	43	17, 18	35	29, 30	43, 44	19-21	372-377	1910
33	41	326	152, 153	82	35	103, 104	9, 10	44	19, 20	36	31, 32	45, 46	22-24	378-385	1911
34	42	327	154, 155	83	36	105, 106	11, 12	45	(11) 1, 2	37	33, 34	47, 48	25-27	386-394	1912
35	43	328	156, 157	84	37	107, 108	13, 14	46	3, 4	38	35, 36	49, 50	28-30	395-401	1913

Zeitschr.f. Elektrochem.	Chem. Abstr.	Z.phys. Chem.	Z.Chem. Ind.Koll.	Z.anorg. Chem.	Z.angew. Chem.	Z.anal. Chem.	Wien. Sitzber.	Proc. Roy.S.	Phil. Trans.	Phil. Mag.	Nature.	Mon. Sci.	Monat. f.Chem.	J.Soc. Dyers	J.Soc. C.Ind.	J.Russ. Soc.	J. pr. Chem.	J.C.S. Trans.	Year.
						20	83,84	31,32	172	11,12	23,24	23	2			13	23,24	39,40	1881
						21	85,86	33	173	13,14	25,26	24	3		1	14	25,26	41,42	1882
						22	87,88	34,35	174	15,16	27,28	25	4		2	15	27,28	43,44	1883
						23	89,90	36,37	175	17,18	29,30	26	5		3	16	29,30	45,46	1884
						24	91,92	38,39		19,20	31,32	27	6	1	4	17	31,32	47,48	1885
						25	93,94	40,41	176	21,22	33,34	28	7	2	5	18	33,34	49,50	1886
		1				26	95,96	42,43	177	23,24	35,36	1	8	3	6	19	35,36	51,52	1887
		2			1	27	97	44,45	178	25,26	37,38	2	9	4	7	20	37,38	53,54	1888
		3,4			2	28	98	46,47	179	27,28	39,40	3	10	5	8	21	39,40	55,56	1889
		6			3	29	99	48,49	180	29,30	41,42	4	11	6	9	22	41,42	57,58	1890
		8			4	30	100	50	181	31,32	43,44	5	12	7	10	23	43,44	59,60	1891
		9,10		1,2	5	31	101	51,52	182	33,34	45,46	6	13	8	11	24	45,46	61,62	1892
		11,12		3,4	6	32	102	53,54	183	35,36	47,48	7	14	9	12	25	47,48	63,64	1893
		13-15		5,7	7	33	103	55,56	184	37,38	49,50	8	15	10	13	26	49,50	65,66	1894
1		16-18		8-10	8	34	104	57	185	39,40	51,52	9	16	11	14	27	51,52	67,68	1895
2		19-21		11,12	9	35	105	59	186,189	41,42	53,54	10	17	12	15	28	53,54	69,70	1896
3		22-24		13-15	10	36	106	60,61	187,191	43,44	55,56	11	18	13	16	29	55,56	71,72	1897
4		25-27		16-18	11	37	107	62,63	190,191	45,46	57,58	12	19	14	17	30	57,58	73,74	1898
5		28-31		19-21	12	38	108	64,65	192	47,48	59,60	13	20	15	18	31	59,60	75,76	1899
6		32-35		22-25	13	39	109	66,67	193,194	49,50	61,62	14	21	16	19	32	61,62	77,78	1900
7		36-38		26-28	14	40	110	68	195,197	1,2 (6)	63,64	15	22	17	20	33	63,64	79,80	1901
8		39-42		29-32	15	41	111	69,70	198,199	3,4	65,66	16	23	18	21	34	65,66	81,82	1902
9		43-46		33-37	16	42	112	71	200,203	5,6	67,68	17	24	19	22	35	67,68	83,84	1903
10		47-49		38-42	17	43	113	72,73	202,204	7,8	69,70	18	25	20	23	36	69,70	85,86	1904
11		50-53		43-47	18	44	114	74-76	206	9,10	71,72	19	26	21	24	37	71,72	87,88	1905
12		54-57		48-51	19	45	115	(A) 77		11,12	73,74	20	27	22	25	38	73,74	89,90	1906
13	1	58-60	1,2	52-55	20	46	116	78,79	207,208	13,14	75,76	21	28	23	26	39	75,76	91,92	1907
14	2	61-64	3	56-60	21	47	117	80,81	209	15,16	77,78	22	29	24	27	40	77,78	93,9.	1908
15	3	65-69	4,5	61-64	22	48	118	82		17,18	79-81	23	30	25	28	41	79,80	95,9.	1909
16	4	70-74	6,7	65-68	23	49	119	83		19,20	82-84	24	31	26	29	42	81,82	97,98	1910
17	5	75-77	8,9	69-72	24	50	120	84,85	210	21,22	85-87	25	32	27	30	43	83,84	99,100	1911
18	6	78-80	10,11	73-76	25	51	121	86,87	211	23,24	88,89	26	33	28	31	44	85,86	101,102	1912
19	7	81-85	12,13	77-80	26	52	122	88	212	25,26	90,91	27	34	29	32	45	87,88	103,104	1913

CONVERSION TABLES FOR WEIGHTS AND MEASURES.

The Regulations of the Board of Trade (March, 1907) state :

" The YARD is the length at 62°F. marked on a bronze bar deposited with the Board of Trade.

" The POUND is the weight of a piece of platinum weighed *in vacuo* at 0°C. which is deposited with the Board of Trade.

" The GALLON contains 10 lbs. weight of distilled water weighed in air against brass weights, with the water and the air at the temperature of 62°F., the barometer being at 30 inches.

" The METRE is the length, at the temperature of 0°C., of the iridio-platinum bar, numbered 16, deposited with the Board of Trade.

" The KILOGRAMME is represented by the iridio-platinum weight, numbered 18, deposited with the Board of Trade.

" The LITRE is represented by the capacity at 0°C. of the cylindrical brass measure, marked ' Litre, 1897 ' (which is deposited with the Board of Trade)."

The legalised fundamental equivalents are as follows :

1 Kilogramme	=	15432·3564 grains
1 Metre	=	39·370113 inches
1 Gallon	=	4·5459631 litres

Circular No. 47 of the U.S. Bureau of Standards states :—

A METER (m) is a unit of length equivalent to the distance between the defining lines on the international prototype meter at the International Bureau of Weights and Measures when this standard is at 0°C.

A YARD (yd.) is a unit of length equivalent to $\frac{3600}{3937}$ of a meter.

A LITER (l) is a unit of capacity equivalent to the volume occupied by the mass of 1 kilogram of pure water at its maximum density (at a temperature of 4° C, practically) and under the standard atmospheric pressure of 760 mm.). It is equivalent in volume to 1·000 027 decimeters.

A GALLON (gal.) is a unit of capacity equivalent to the volume of 231 cubic inches.

A KILOGRAM (kg) is a unit of mass equivalent to the mass of
the international prototype kilogram at the International
Bureau of Weights and Measures.
An AVOIRDUPOIS POUND (lb. av.) is a unit of mass equivalent to
0·453 592 427 7 kilogram.

Linear Measures.

		Log. of factor.
1 inch	2.5400 cm.	0.40483
1 link (=7.92 inches)	20.117 cm.	1.30356
1 foot (=12 inches)	30.480 cm.	1.48401
1 yard (=3 feet)	91.440 cm.	1.96114
1 pole (=5½ yards)	5.0292 metres	0.70150
1 chain (=100 links)	20.117 metres	1.30356
1 furlong (=40 poles)	201.17 metres	2.30356
1 mile (=8 furlongs)	1609.34 metres	3.20665
1 centimetre	0.39370 inches	$\bar{1}$.59517
1 metre	3.2808 feet	0.51598
	or 1.0936 yards	0.03886
1 kilometre	0.62137 mile	$\bar{1}$.79335

1 micron (μ) = 0.000001 metre = 0.001 millimetre
1 millimicron (m μ) = 0.001 micron.

Superficial Measures.

		Log. of factor.
1 sq. in.	6.4516 sq. cm.	0.80967
1 sq. ft. (=144 sq. ins.)	929.03 sq. cm.	2.96803
1 sq. yd. (=9 sq. ft.)	8361.26 sq. cm.	3.92228
1 acre (=4840 sq. yds.)	4046.85 sq. metres	3.60712
	or 40.4685 ares	1.60712
1 sq. mile (=640 acres)	25899.8 ares	4.41330
	or 2.58998 sq. kilometres	0.41330
		Log. of factor
1 sq. cm.	0.15500 sq. in.	1.19033
1 sq. m.	1550.0 sq. in.	3.19033
	or 10.764 sq. ft.	1.03197
	or 1.1960 sq. yds.	0.07773
1 are (dkm²)	119.60 sq. yds.	2.07773
1 hectare (hm²)	2.4711 acres	0.39289
1 sq. km.	0.38610 sq. m.	$\bar{1}$.58670

Cubical Measures.

		Log. of factor.
1 c. in.	16.387 cc.	1.21450
1 c. ft. (=1728 c. in.)	28316 cc	4.45203
1 c. yd. (=27 c. ft.)	0.76455 c.m. (or stere)	$\bar{1}$.88341
1 cc.	0.061024 c. in.	$\bar{2}$.78550
1 litre	0.035315 c. ft.	$\bar{2}$.54796
1 stere or c.m.	35.315 c. ft.	1.54796
	or 1.30795 c. yds.	0.11659

1 cu. ft. of water weighs 62·335 lbs.

Measures of Capacity.

Imperial units.	Metric units.	Log. of factor
1 minim ($\mathfrak{m}$)	0.059192 cc.	2.77226
1 fluid scruple	1.1838 cc.	0.07327
1 fluid drachm (=60 minims)	3.5515 cc	0.55041
1 fluid ounce (fl. $\mathfrak{z}$)	28.412 cc.	1.45350
1 gill (=5 fl. oz.)	0.14206 litres	$\bar{1}$.15247
1 pint (=4 gills)	0.56825 litres	$\bar{1}$.75454
1 gallon (=8 pints)	4.5460 litres	0.65763
1 peck (=2 gallons)	9.0919 litres	0.95865
1 bushel (=4 pecks)	36.368 litres	1.56072
1 quarter (=8 bushels)	290.94 litres	2.46380

Metric units.	Imperial units.	Log. of factor
1 cc.	0.0070392 gills	3.84752
1 litre	1.7598 pints	0.24547
	or 0.21998 gallons	$\bar{1}$.34239
1 decalitre	1.0999 pecks	0.04136
1 hectolitre	2.7497 bushels	0.43928

1 Imperial gallon of water weighs 10 lbs. and occupies 0·1604 cu. ft.

Measures of Capacity used in B.P., 1914.

1 centimil (Cl)	= 0.01 cc. =	0.169 minims.
1 decimil (Dl)	= 0.1 cc. =	1.69 minims
1 millilitre or mil (Ml)	= 1 cc. =	16.9 minims.
1 litre (Lit)	=1000 cc. =	35.196 fluid ozs.

U.S. Measures of Capacity.

		Log. of factor.
1 minim (min. or ♏︎)	0.06161 millilitres	$\bar{2}.78965$
1 fluid dram (60 minims)	3.6966 ,,	0.56780
1 fluid ounce (8 fl. dr.)	29.573 ,,	1.47089
1 gill (4 fl. oz.)	0.11829 litres	$\bar{1}.07295$
1 pint (4 gills)	0.47317 ,,	$\bar{1}.67501$
1 quart (2 pints)	0.94633 ,,	$\bar{1}.97604$
1 gallon (4 quarts)	3.78533 ,,	0.57811
1 dry pint	0.5506 ,,	$\bar{1}.74084$
1 dry quart (2 dry pints)	1.1012 ,,	0.04187
1 peck (8 dry quarts)	8.810 ,,	0.94498
1 bushel (4 pecks)	0.35238 hectolitres	$\bar{1}.54701$
1 cubic centimetre	0.27051 fluid drams	$\bar{1}.43219$
1 millimetre	0.27052 ,,	$\bar{1}.43220$
1 litre	2.1134 pints	0.32498
	or 0.26418 gallons	$\bar{1}.42190$
1 decalitre	2.6418 ,,	0.42190
1 hectolitre	26.418 ,,	1.42190

1 U.S. gallon of water weighs 8·33 lbs. and occupies 0·1336 cu. ft.

Relations of British and American Units.

1 U.S. gallon=0.83268 Imperial gallon
1 U.S. bushel=0.96945 Imperial bushel
1 Imperial gallon=1.20094 U.S. gallon
1 Imperial bushel=1.03151 U.S. bushel
1 British gallon ale or beer=1.2208 U.S. gallon
Barrel (British) or tierce=42 gallons
Barrel (U.S. liquid, oil, etc.)=31.5 gallons

Measures of Weight.

		Log. of factor.
1 grain	0.064799 grm.	2.81157
1 dram (avoir)	1.7718 grm.	0.24842
1 ounce ,,	28.3495 grm.	1.45255
1 pound ,,	453.5924 grm.	2.65666
1 stone ,,	6.3505 kgm.	0.80279
1 quarter ,,	12.7006 kgm.	1.10382
1 short hundredweight (100 lbs.)	45.3592 kgm.	1.65666
1 long ,, (112 lbs.)	50.8024 kgm.	1.70588
1 short ton (2000 lbs.)	0.90718 metric tons	$\bar{1}$.95770
1 long ,, (2240 lbs.)	1.01605 metric tons	0.00691

		Log. of factor.
1 scruple (apoth.)	1.2960 grm.	0.11260
1 pennyweight (troy)	1.5552 grm.	0.19179
1 drachm ($\mathrecal{z}$) (apoth.)	3.8879 grm.	0.58971
1 ounce ($\mathrecal{z}$) (troy and apoth.)	31.103 grm.	1.49280
1 pound (troy and apoth.)	373.24 grm.	2.57199

			Log. of factor.
1 metric carat (0.2 grm.)	3.0865 grains		0.48947
1 gramme	15.432 grains		1.18843
	or	0.56438 drams (avoir.)	$\bar{1}$.75157
	or	0.035274 oz. (avoir.)	$\bar{2}$.54746
1 kilogramme	2.2046 lbs.		0.34333
1 metric ton	0.98420 ton		$\bar{1}$.99308

Signs used for Medical Prescriptions.

½ grain	... gr. ss.		1 drachm	... ʒ i, or ʒ j.
1 ,,	... gr. j, or gr. i.		1½ ,,	... ʒ iss.
1½ ,,	... gr. iss.		2 ,,	... ʒ ii, or ʒ ij.
2 ,,	... gr. ii, or gr. ij.		3 ,,	... ʒ iii, or ʒ iij
2½ ,,	... gr. iiss.		3½ ,,	... ʒ iiiss.
4 ,,	... gr. iv.		½ ounce	... ℥ ss.
8 ,,	... gr. viii. or gr. viij.		1 ,,	... ℥ i, or ℥ j.
½ scruple	... ℈ ss.		1½ ,,	... ℥ iss.
1 ,,	... ℈ i. or ℈ j.		½ pint	... Oss.
1½ ,,	... ℈ iss.		1 ,,	... Oi or Oj.
2 ,,	... ℈ ii, or ℈ ij.		1 gallon	... Ci or Cj

Conversion of degrees Centigrade to degrees Fahrenheit and degrees Réaumur.

Cent.	Fahr.	Réaumur.	Cent.	Fahr.	Réaumur.
−40	−40	−32	+14	+57.2	+11.2
39	38.2	31.2	15	59	12
38	36.4	30.4	16	60.8	12.8
37	34.6	29.6	17	62.6	13.6
36	32.8	28.8	18	64.4	14.4
35	31	28	19	66.2	15.2
34	29.2	27.2	20	68	16
33	27.4	26.4	21	69.8	16.8
32	25.6	25.6	22	71.6	17.6
31	23.8	24.8	23	73.4	18.4
30	22	24	24	75.2	19.2
29	20.2	23.2	25	77	20
28	18.4	22.4	26	78.8	20.8
27	16.6	21.6	27	80.6	21.6
26	14.8	20.8	28	82.4	22.4
25	13	20	29	84.2	23.2
24	11.2	19.2	30	86	24
23	9.4	18.4	31	87.8	24.8
22	7.6	17.6	32	89.6	25.6
21	5.8	16.8	33	91.4	26.4
20	4	16	34	93.2	27.2
19	2.2	15.2	35	95	28
18	0.4	14.4	36	96.8	28.8
17	+1.4	13.6	37	98.6	29.6
16	3.2	12.8	38	100.4	30.4
15	5	12	39	102.2	31.2
14	6.8	11.2	40	104	32
13	8.6	10.4	41	105.8	32.8
12	10.4	9.6	42	107.6	33.6
11	12.2	8.8	43	109.4	34.4
10	14	8	44	111.2	35.2
9	15.8	7.2	45	113	36
8	17.6	6.4	46	114.8	36.8
7	19.4	5.6	47	116.6	37.6
6	21.2	4.8	48	118.4	38.4
5	23	4	49	120.2	39.2
4	24.8	3.2	50	122	40
3	26.6	2.4	51	123.8	40.8
2	28.4	1.6	52	125.6	41.6
1	30.2	0.8	53	127.4	42.4
0	32	0	54	129.2	43.2
+1	33.8	+0.8	55	131	44
2	35.6	1.6	56	132.8	44.8
3	37.4	2.4	57	134.6	45.6
4	39.2	3.2	58	136.4	46.4
5	41	4	59	138.2	47.2
6	42.8	4.8	60	140	48
7	44.6	5.6	61	141.8	48.8
8	46.4	6.4	62	143.6	49.6
9	48.2	7.2	63	145.4	50.4
10	50	8	64	147.2	51.2
11	51.8	8.8	65	149	52
12	53.6	9.6	66	150.8	52.8
13	55.4	10.4	67	152.6	53.6

Cent.	Fahr.	Réaumur.	Cent.	Fahr.	Réaumur.
68	154.4	54.4	85	185	68
69	156.2	55.2	86	186.8	68.8
70	158	56	87	188.6	69.6
71	159.8	56.8	88	190.4	70.4
72	161.6	57.6	89	192.2	71.2
73	163.4	58.4	90	194	72
74	165.2	59.2	91	195.8	72.8
75	167	60	92	197.6	73.6
76	168.8	60.8	93	199.4	74.4
77	170.6	61.6	94	201.2	75.2
78	172.4	62.4	95	203	76
79	174.2	63.2	96	204.8	76.8
80	176	64	97	206.6	77.6
81	177.8	64.8	98	208.4	78.4
82	179.6	65.6	99	210.2	79.2
83	181.4	66.4	100	212	80
84	183.2	67.2			

Conversion of degrees Fahrenheit to degrees Centigrade and degrees Réaumur.

Fahr.	Cent.	Réaumur.	Fahr.	Cent.	Réaumur.
− 40	− 40	− 32	− 13	− 25	− 20
39	39.44	31.56	12	24.44	19.56
38	38.89	31.11	11	23.89	19.11
37	38.33	30.67	10	23.33	18.67
36	37.78	30.22	9	22.78	18.22
35	37.22	29.78	8	22.22	17.78
34	36.67	29.33	7	21.67	17.33
33	36.11	28.89	6	21.11	16.89
32	35.55	28.44	5	20.55	16.44
31	35	28	4	20	16
30	34.44	27.56	3	19.44	15.56
29	33.89	27.11	2	18.89	15.11
28	33.33	26.67	1	18.33	14.67
27	32.78	26.22	0	17.78	14.22
26	32.22	25.78	+1	17.22	13.78
25	31.67	25.33	2	16.67	13.33
24	31.11	24.89	3	16.11	12.89
23	30 56	24.44	4	15.55	12.44
22	30	24	5	15	12
21	29.44	23.56	6	14.44	11.56
20	28.89	23.11	7	13.89	11.11
19	28.33	22.67	8	13.33	10.67
18	27.78	22.22	9	12.78	10.22
17	27.22	21.78	10	12.22	9.78
16	26.67	21.33	11	11.67	9.33
15	26.11	20.89	12	11.11	8.89
14	25.55	20.44	13	10.55	8.44

Fahr.	Cent.	Réaumur.	Fahr.	Cent.	Réaumur.
+14	−10	−8	+70	+21.11	+16.89
15	9.44	7.56	71	21.67	17.33
16	8.89	7.11	72	22.22	17.78
17	8.33	6.67	73	22.78	18.22
18	7.78	6.22	74	23.33	18.67
19	7.22	5.78	75	23.89	19.11
20	6.67	5.33	76	24.44	19.56
21	6.11	4.89	77	25	20
22	5.55	4.44	78	25.55	20.44
23	5	4	79	26.11	20.89
24	4.44	3.56	80	26.67	21.33
25	3.89	3.11	81	27.22	21.78
26	3.33	2.67	82	27.78	22.22
27	2.78	2.22	83	28.33	22.67
28	2.22	1.78	84	28.89	23.11
29	1.67	1.33	85	29.44	23.56
30	1.11	0.89	86	30	24
31	0.55	0.44	87	30.55	24.44
32	0	0	88	31.11	24.89
33	+0.55	+0.44	89	31.67	25.33
34	1.11	0.89	90	32.22	25.78
35	1.67	1.33	91	32.78	26.22
36	2.22	1.78	92	33.33	26.67
37	2.78	2.22	93	33.89	27.11
38	3.33	2.67	94	34.44	27.56
39	3.89	3.11	95	35	28
40	4.44	3.56	96	35.55	28.44
41	5	4	97	36.11	28.89
42	5.55	4.44	98	36.67	29.33
43	6.11	4.89	99	37.22	29.78
44	6.67	5.33	100	37.78	30.22
45	7.22	5.78	101	38.33	30.67
46	7.78	6.22	102	38.89	31.11
47	8.33	6.67	103	39.44	31.56
48	8.89	7.11	104	40	32
49	9.44	7.56	105	40.55	32.44
50	10	8	106	41.11	32.89
51	10.55	8.44	107	41.67	33.33
52	11.11	8.89	108	42.22	33.78
53	11.67	9.33	109	42.78	34.22
54	12.22	9.78	110	43.33	34.67
55	12.78	10.22	111	43.89	35.11
56	13.33	10.67	112	44.44	35.56
57	13.89	11.11	113	45	36
58	14.44	11.56	114	45.55	36.44
59	15	12	115	46.11	36.89
60	15.56	12.44	116	46.67	37.33
61	16.11	12.89	117	47.22	37.78
62	16.67	13.33	118	47.78	38.22
63	17.22	13.78	119	48.33	38.67
64	17.78	14.22	120	48.89	39.11
65	18.33	14.67	121	49.44	39.56
66	18.89	15.11	122	50	40
67	19.44	15.56	123	50.55	40.44
68	20	16	124	51.11	40.89
69	20.55	16.44	125	51.67	41.33

Fahr.	Cent.	Réaumur.	Fahr.	Cent.	Réaumur.
+126	+52.22	+41.78	+170	+76.67	+61.33
127	52.78	42.22	171	77.22	61.78
128	53.33	42.67	172	77.78	62.22
129	53.89	43.11	173	78.33	62.67
130	54.44	43.56	174	78.89	63.11
131	55	44	175	79.44	63.56
132	55.55	44.44	176	80	64
133	56.11	44.89	177	80.55	64.44
134	56.67	45.33	178	81.11	64.89
135	57.22	45.78	179	81.67	65.33
136	57.78	46.22	180	82.22	65.78
137	58.33	46.67	181	82.78	66.22
138	58.89	47.11	182	83.33	66.67
139	69.44	47.56	183	83.89	67.11
140	60	48	184	84.44	67.56
141	60.55	48.44	185	85	68
142	61.11	48.89	186	85.55	68.44
143	61.67	49.33	187	86.11	68.89
144	62.22	49.78	188	86.67	69.33
145	62.78	50.22	189	87.22	69.78
146	63.33	50.67	190	87.78	70.22
147	63.89	51.11	191	88.33	70.67
148	64.44	51.56	192	88.89	71.11
149	65	52	193	89.44	71.56
150	65.55	52.44	194	90	72
151	66.11	52.89	195	90.55	72.44
152	66.67	53.33	196	91.11	72.89
153	67.22	53.78	197	91.67	73.33
154	67.78	54.22	198	92.22	73.78
155	68.33	54.67	199	92.78	74.22
156	68.89	55.11	200	93.33	74.67
157	69.44	55.56	201	93.89	75.11
158	70	56	202	94.44	75.56
159	70.55	56.44	203	95	76
160	71.11	56.89	204	95.55	76.44
161	71.67	57.33	205	96.11	76.89
162	72.22	57.78	206	96.67	77.33
163	72.78	58.22	207	97.22	77.78
164	73.33	58.67	208	97.78	78.22
165	73.89	59.11	209	98.33	78.67
166	74.44	59.56	210	98.89	79.11
167	75	60	211	99.44	79.56
168	75.55	60.44	212	100	80
169	76.11	60.89			

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
105	221	140	284	175	347
110	230	145	293	180	356
115	239	150	302	185	365
120	248	155	311	190	374
125	257	160	320	200	392
130	266	165	329	250	482
135	275	170	338	300	572

Barometer Readings.

CONVERSION OF INCHES INTO MILLIMETRES OF MERCURY.

in.	0	1	2	3	4	5	6	7	8	9
29.0	736.59	736.85	737.10	737.36	737.61	737.86	738.12	738.37	738.63	738.88
29.1	739.13	739.39	739.64	739.90	740.15	740.40	740.66	740.91	741.17	741.42
29.2	741.67	741.93	742.18	742.44	742.69	742.94	743.20	743.45	743.71	743.96
92.3	744.21	744.47	744.72	744.98	745.23	745.48	745.74	745.99	746.25	746.50
29.4	746.75	747.01	747.26	747.52	747.77	748.02	748.27	748.53	748.78	749.04
29.5	749.29	749.55	749.80	750.06	750.31	750.56	750.82	751.07	751.33	751.58
29.6	751.83	752.09	752.34	752.60	752.85	753.10	753.36	753.61	753.87	754.12
29.7	754.37	754.63	754.88	755.14	755.39	755.64	755.90	756.15	756.41	756.65
29.8	756.91	757.17	757.42	757.68	757.93	758.18	758.44	758.69	758.95	759.20
29.9	759.45	759.71	759.96	760.22	760.47	760.72	760.98	761.23	761.49	761.74
30.0	761.99	7b2.25	762.50	762.76	763.01	763.26	763.52	763.77	764.03	764.28
30.1	764.53	764.79	765.04	765.30	765.55	765.80	766.06	766.31	766.57	766.82
30.2	767.07	767.33	767.58	767.84	768.09	768.34	768.60	768.85	769.11	769.36
30.3	769.61	769.87	770.12	770.38	770.63	770.88	771.14	771.39	771.65	771.90
30.4	772.15	772.41	772.66	772.92	773.17	773.42	773.68	773.93	774.19	774.44
30.5	774.69	774.95	775.20	775.46	775.71	775.96	776.22	776.47	776.73	776.98
30.6	777.23	777.49	777.74	778.00	778.25	778.50	778.76	779.01	779.27	779.52
30.7	779.77	780.03	780.28	780.54	780.79	781.04	781.30	781.55	781.81	782.06
30.8	782.31	782.57	782.82	783.08	783.33	783.58	783.84	784.09	784.35	784.60
30.9	784.85	785.11	785.36	785.62	785 87	786.12	786.38	786.63	786.89	787.14
31.0	787.39	787.65	787.90	788.16	788.41	788.66	788.82	789.17	789.43	789.68

CONVERSION OF MILLIMETRES INTO INCHES OF MERCURY.

mm.	0	1	2	3	4	5	6	7	8	9
700	27.56	27.60	27.64	27.68	27.72	27.76	27.80	27.84	27.88	27.91
710	27.95	27.99	28.03	28.07	28.11	28.15	28.19	28.23	28.27	28.31
720	28.35	28.39	28.43	28.47	28.50	28.54	28.58	28.62	28.66	28.70
730	28.74	28.78	28.82	28.86	28.90	28.94	28.98	29.02	29.06	29.10
740	29.13	29.17	29.21	29.25	29.29	29.33	29.37	29.41	29.45	29.49
750	29.53	29.57	29.61	29.65	29.69	29.73	29.77	29.80	29.84	29.88
760	29.92	29.96	30.00	30.04	30.08	30.12	30.16	30.20	30.24	30.28
770	30.32	30.36	30.39	30.43	30.47	30.51	30.55	30.59	30.63	30.67
780	30.71	30.75	30.79	30.83	30.87	30.91	30.95	30.99	31.02	31.06

HYDROMETRIC TABLES.

The *Twaddell Hydrometer*, generally employed in England, has a scale of from 0° to 200°, corresponding to change in Specific Gravity from 1 to 2, the degrees representing constant increases. Water at 4°C. is considered to have a Specific Gravity of 1000 units, hence an increase in Specific Gravity of 5 units corresponds to an increase of 1° Tw.

Conversion of degrees Twaddell to Specific Gravity:

$$\text{Specific Gravity} = 1 + \frac{5(°\text{Tw.})}{1000}$$

The original Baumé Hydrometer scale is graduated so that for liquids heavier than water, 0° is the point to which the hydrometer sinks in water, and 10° the point to which it sinks in a 10% solution of sodium chloride; for liquids lighter than water, 0° is the point to which the hydrometer sinks in the 10% solution of sodium chloride, and 10° the point to which it sinks in water, both liquids being at 17·5°C. The conversion may be calculated from the following formulæ :—

For liquids heavier than water,

$$\text{Specific Gravity} = \frac{146 \cdot 78}{146 \cdot 78 - °\text{Bé.}}$$

For liquids lighter than water,

$$\text{Specific Gravity} = \frac{146 \cdot 78}{136 \cdot 78 + °\text{Bé.}}$$

The *continental* Baumé Hydrometer has the " rational " scale proposed by Lunge, in which 0° is the point to which the hydrometer sinks in water, and 66° the point to which it sinks in sulphuric acid of Sp. gr. 1·842, both liquids being at 15°C.

Baumé " rational " scale :

Specific Gravity at 15°C. (compared to water at 15°C. = 1)

$$= \frac{144\cdot3}{144\cdot3 - °Bé.}$$

The *American* Baumé Hydrometer scale, adopted by the Manufacturing Chemists' Association of the United States, is calculated from the following formulæ, according to the Bureau of Standards, Circulars 19 and 57 :—

For liquids heavier than water at 60°F. (= 15·55°C.),

$$°Bé = 145 - \frac{145}{Sp. Gr.} \; ; \; \text{Specific Gravity} = \frac{145}{145 - °Bé.}$$

For liquids lighter than water,

$$°Bé = \frac{140}{Sp. Gr.} - 130 \; ; \; \text{Specific Gravity} = \frac{140}{130 + °Bé.}$$

Conversion of " rational " degrees Baumé (heavier than water) to Specific Gravity.

°Bé.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
–	1.000	1.007	1.014	1.021	1.029	1.036	1.043	1.051	1.059	1.066
10	1.074	1.082	1.091	1.099	1.107	1.116	1.125	1.134	1.143	1.152
20	1.161	1.170	1.180	1.190	1.200	1.210	1.220	1.230	1.241	1.251
30	1.262	1.274	1.285	1.296	1.308	1.320	1.332	1.345	1.357	1.370
40	1.384	1.397	1.411	1.424	1.439	1.453	1.468	1.483	1.498	1.514
50	1.530	1.547	1.563	1.580	1.598	1.616	1.634	1.652	1.672	1.692
60	1.712	1.732	1.753	1.775	1.797	1.820	1.843	1.867	1.891	1.916

Conversion of American degrees Baumé (heavier than water) to Specific Gravity.

°Bé	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
—	1.000	1.007	1.014	1.021	1.028	1.036	1.043	1.051	1.058	1.066
10	1.074	1.082	1.090	1.098	1.107	1.115	1.124	1.133	1.142	1.151
20	1.160	1.169	1.179	1.188	1.198	1.208	1.218	1.229	1.239	1.250
30	1.261	1.272	1.283	1.295	1.306	1.318	1.330	1.343	1.355	1.368
40	1.381	1.394	1.408	1.422	1.436	1.450	1.465	1.480	1.495	1.510
50	1.526	1.543	1.559	1.576	1.593	1.611	1.629	1.648	1.667	1.686
60	1.706	1.726	1.747	1.768	1.790	1.812	1.835	1.859	1.883	1.908

Conversion of American degrees Baumé (lighter than water) to Specific Gravity.

°Bé	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
10	1.000	0.993	0.986	0.979	0.972	0.966	0.959	0.952	0.946	0.940
20	0.933	0.927	0.921	0.915	0.909	0.903	0.897	0.892	0.886	0.880
30	0.875	0.870	0.864	0.859	0.854	0.848	0.843	0.838	0.833	0.828
40	0.824	0.819	0.814	0.809	0.804	0.800	0.795	0.791	0.786	0.782
50	0.778	0.773	0.769	0.765	0.761	0.757	0.753	0.749	0.745	0.741
60	0.737	0.733	0.729	0.725	0.722	0.718	0.714	0.711	0.707	0.704
70	0.700	0.696	0.693	0.690	0.686	0.683	0.680	0.676	0.673	0.670
80	0.667	0.664	0.660	0.657	0.654	0.651	0.648	0.645	0.642	0.639
90	0.636	0.633	0.631	0.628	0.625	0.622	0.619	0.617	0.614	0.611

FIVE-FIGURE LOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
100	00000	043	087	130	173	217	260	303	346	389	4	8	13	17	21	26	30	35	39
101	432	475	518	561	604	647	689	732	775	817	4	8	13	17	21	26	30	34	39
102	860	903	945	988	030	072	115	157	199	242	4	8	13	17	21	25	30	34	38
103	01284	326	368	410	452	494	536	578	620	662	4	8	13	17	21	25	30	34	38
104	703	745	787	828	870	912	953	995	036	078	4	8	12	17	21	25	29	34	38
105	02119	160	202	243	284	325	366	407	449	490	4	8	12	17	21	25	29	33	37
106	531	572	612	653	694	735	776	816	857	898	4	8	12	16	20	24	29	33	37
107	938	979	019	060	100	141	181	222	262	302	4	8	12	16	20	24	28	32	36
108	03342	383	423	463	503	543	583	623	663	703	4	8	12	16	20	24	28	32	36
109	743	782	822	862	902	941	981	021	060	100	4	8	12	16	20	24	28	32	36
110	04139	179	218	258	297	336	376	415	454	493	4	8	12	16	20	24	27	31	35
111	532	571	610	650	689	727	766	805	844	883	4	8	12	16	20	23	27	31	35
112	922	961	999	038	077	115	154	192	231	269	4	8	12	16	20	23	27	31	35
113	05308	346	385	423	461	500	538	576	614	652	4	8	11	15	19	23	27	30	34
114	690	729	767	805	843	881	918	956	994	032	4	8	11	15	19	23	26	30	34
115	06070	108	145	183	221	258	296	333	371	408	4	8	11	15	19	23	26	30	34
116	446	483	521	558	595	633	670	707	744	781	4	7	11	15	19	22	26	30	33
117	819	856	893	930	967	004	041	078	115	151	4	7	11	15	19	22	25	29	33
118	07188	225	262	298	335	372	408	445	482	518	4	7	11	15	18	22	25	29	33
119	555	591	628	664	700	737	773	809	846	882	4	7	11	15	18	22	25	29	32
120	918	954	990	027	063	099	135	171	207	243	4	7	11	14	18	22	25	29	32
121	08279	314	350	386	422	458	493	529	565	600	4	7	11	14	18	21	25	29	32
122	636	672	707	743	778	814	849	884	920	955	4	7	11	14	18	21	25	28	32
123	991	025	061	096	132	167	202	237	272	307	4	7	11	14	18	21	25	28	32
124	09342	377	412	447	482	517	552	587	621	656	3	7	10	14	18	21	24	28	31
125	691	726	760	795	830	864	899	934	968	003	3	7	10	14	17	21	24	28	31
126	10037	072	106	140	175	209	243	278	312	346	3	7	10	14	17	21	24	27	31
127	380	415	449	483	517	551	585	619	653	687	3	7	10	14	17	20	24	27	31
128	721	755	789	823	856	890	924	958	992	025	3	7	10	14	17	20	24	27	30
129	11059	093	126	160	193	227	260	294	327	361	3	7	10	14	17	20	24	27	30
130	394	428	461	494	528	561	594	628	661	694	3	7	10	13	17	20	23	27	30
131	727	760	793	826	860	893	926	959	992	024	3	7	10	13	17	20	23	26	30
132	12057	090	123	156	189	222	254	287	320	352	3	7	10	13	16	20	23	26	29
133	385	418	450	483	516	548	581	613	646	678	3	6	10	13	16	20	23	26	29
134	710	743	775	808	840	872	905	937	969	001	3	6	10	13	16	19	23	26	29
135	13033	066	098	130	162	194	226	258	290	322	3	6	10	13	16	19	22	26	29
136	354	386	418	450	481	513	545	577	609	640	3	6	10	13	16	19	22	25	29
137	672	704	735	767	799	830	862	893	925	956	3	6	10	13	16	19	22	25	28
138	988	019	051	082	114	145	176	208	239	270	3	6	9	13	16	19	22	25	28
139	14301	333	364	395	426	457	489	520	551	582	3	6	9	12	16	19	22	25	28

140] Five-figure Logarithms—*continued*. ['14

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
140	14613	644	675	706	737	768	799	829	860	891	3	6	9	12	15	19	22	25	28
141	922	953	983	*014*	*045*	*076*	*106*	*137*	*168*	*198*	3	6	9	12	15	18	21	25	28
142	15229	259	290	320	351	381	412	442	473	503	3	6	9	12	15	18	21	24	27
143	534	564	594	625	655	685	715	746	776	806	3	6	9	12	15	18	21	24	27
144	836	866	897	927	957	987	*017*	*047*	*077*	*107*	3	6	9	12	15	18	21	24	27
145	16137	167	197	227	256	286	316	346	376	406	3	6	9	12	15	18	21	24	27
146	435	465	495	524	554	584	613	643	673	702	3	6	9	12	15	18	21	24	27
147	732	761	791	820	850	879	909	938	967	997	3	6	9	12	15	18	21	24	26
148	17026	056	085	114	143	173	202	231	260	289	3	6	9	12	15	18	20	23	26
149	319	348	377	406	435	464	493	522	551	580	3	6	9	12	15	17	20	23	26
150	609	638	667	696	725	754	782	811	840	869	3	6	9	12	14	17	20	23	26
151	898	926	955	984	*013*	*041*	*070*	*099*	*127*	*156*	3	6	9	11	14	17	20	23	26
152	18184	213	241	270	298	327	355	384	412	441	3	6	9	11	14	17	20	23	25
153	469	498	526	554	583	611	639	667	696	724	3	6	9	11	14	17	20	23	25
154	752	780	808	837	865	893	921	949	977	*005*	3	6	8	11	14	17	20	23	25
155	19033	061	089	117	145	173	201	229	257	285	3	6	8	11	14	17	20	22	25
156	312	340	368	396	424	451	479	507	535	562	3	6	8	11	14	17	20	22	25
157	590	618	645	673	700	728	756	783	811	838	3	5	8	11	14	17	19	22	25
158	866	893	921	948	976	*003*	*030*	*058*	*085*	*112*	3	5	8	11	14	16	19	22	25
159	20140	167	194	222	249	276	303	330	358	385	3	5	8	11	14	16	19	22	25
160	412	439	466	493	520	547	575	602	629	656	3	5	8	11	14	16	19	22	24
161	683	710	736	763	790	817	844	871	898	925	3	5	8	11	13	16	19	22	24
162	951	978	*005*	*032*	*059*	*085*	*112*	*139*	*165*	*192*	3	5	8	11	13	16	19	21	24
163	21219	245	272	299	325	352	378	405	431	458	3	5	8	11	13	16	19	21	24
164	484	511	537	564	590	617	643	669	696	722	3	5	8	11	13	16	18	21	24
165	748	775	801	827	854	880	906	932	958	985	3	5	8	10	13	16	18	21	24
166	22011	037	063	089	115	141	167	194	220	246	3	5	8	10	13	16	18	21	23
167	272	298	324	350	376	401	427	453	479	505	3	5	8	10	13	16	18	21	23
168	531	557	583	608	634	660	686	712	737	763	3	5	8	10	13	15	18	21	23
169	789	814	840	866	891	917	943	968	994	*019*	3	5	8	10	13	15	18	21	23
170	23045	070	096	121	147	172	198	223	249	274	3	5	8	10	13	15	18	20	23
171	300	325	350	376	401	426	452	477	502	528	3	5	8	10	13	15	18	20	23
172	553	578	603	629	654	679	704	729	754	779	3	5	8	10	13	15	18	20	23
173	805	830	855	880	905	930	955	980	*005*	*030*	2	5	7	10	13	15	18	20	23
174	24055	080	105	130	155	180	204	229	254	279	2	5	7	10	12	15	17	20	22
175	304	329	353	378	403	428	452	477	502	527	2	5	7	10	12	15	17	20	22
176	551	576	601	625	650	674	699	724	748	773	2	5	7	10	12	15	17	20	22
177	797	822	846	871	895	920	944	969	993	*018*	2	5	7	10	12	15	17	20	22
178	25042	066	091	115	139	164	188	212	237	261	2	5	7	10	12	15	17	19	22
179	285	310	334	358	382	406	431	455	479	503	2	5	7	10	12	15	17	19	22

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180	25527	551	575	600	624	648	672	696	720	744	2	5	7	10	12	14	17	19	22
181		768	792	816	840	864	888	912	935	959	983	2	5	7	10	12	14	17	19	22
182	26007	031	055	079	102	126	150	174	198	221	2	5	7	10	12	14	17	19	21
183		245	269	293	316	340	364	387	411	435	458	2	5	7	10	12	14	17	19	21
184		482	505	529	553	576	600	623	647	670	694	2	5	7	9	12	14	17	19	21
185		717	741	764	788	811	834	858	881	905	928	2	5	7	9	12	14	16	19	21
186		951	975	998	*021*	*045*	*068*	*091*	*114*	*138*	*161*	2	5	7	9	12	14	16	19	21
187	27184	207	231	254	277	300	323	346	370	393	2	5	7	9	12	14	16	19	21
188		416	439	462	485	508	531	554	577	600	623	2	5	7	9	12	14	16	18	21
189		646	669	692	715	738	761	784	807	829	852	2	5	7	9	11	14	16	18	21
190		875	898	921	944	967	989	*012*	*035*	*058*	*081*	2	5	7	9	11	14	16	18	21
191	28103	126	149	171	194	217	240	262	285	307	2	5	7	9	11	14	16	18	20
192		330	353	375	398	420	443	466	488	510	533	2	5	7	9	11	14	16	18	20
193		556	578	601	623	646	668	691	713	735	758	2	4	7	9	11	13	16	18	20
194		780	803	825	847	870	892	914	937	959	981	2	4	7	9	11	13	16	18	20
195	29003	026	048	070	092	115	137	159	181	203	2	4	7	9	11	13	16	18	20
196		226	248	270	292	314	336	358	380	403	425	2	4	7	9	11	13	15	18	20
197		447	469	491	513	535	557	579	601	623	645	2	4	7	9	11	13	15	18	20
198		667	688	710	732	754	776	798	820	842	863	2	4	7	9	11	13	15	18	20
199		885	907	929	951	973	994	*016*	*038*	*060*	*081*	2	4	7	9	11	13	15	17	20
200	30103	125	146	168	190	211	233	255	276	298	2	4	7	9	11	13	15	17	20
201		320	341	363	384	406	428	449	471	492	514	2	4	6	9	11	13	15	17	19
202		535	557	578	600	621	642	664	685	707	728	2	4	6	9	11	13	15	17	19
203		750	771	792	814	835	856	877	899	920	942	2	4	6	9	11	13	15	17	19
204		963	984	*006*	*027*	*048*	*069*	*091*	*112*	*133*	*154*	2	4	6	8	11	13	15	17	19
205	31175	197	218	239	260	281	302	323	345	366	2	4	6	8	11	13	15	17	19
206		387	408	429	450	471	492	513	534	555	576	2	4	6	8	11	13	15	17	19
207		597	618	639	660	681	702	723	744	765	785	2	4	6	8	10	13	15	17	19
208		806	827	848	869	890	911	931	952	973	994	2	4	6	8	10	13	15	17	19
209	32015	035	056	077	098	118	139	160	181	201	2	4	6	8	10	12	15	17	19
210		222	243	263	284	305	325	346	366	387	408	2	4	6	8	10	12	14	16	18
211		428	449	469	490	510	531	552	572	593	613	2	4	6	8	10	12	14	16	18
212		634	654	675	695	715	736	756	777	797	818	2	4	6	8	10	12	14	16	18
213		838	858	879	899	919	940	960	980	*001*	*021*	2	4	6	8	10	12	14	16	18
214	33041	062	082	102	122	143	163	183	203	224	2	4	6	8	10	12	14	16	18
215		244	264	284	304	325	345	365	385	405	425	2	4	6	8	10	12	14	16	18
216		445	465	486	506	526	546	566	586	606	626	2	4	6	8	10	12	14	16	18
217		646	666	686	706	726	746	766	786	806	826	2	4	6	8	10	12	14	16	18
218		846	866	885	905	925	945	965	985	*005*	*025*	2	4	6	8	10	12	14	16	18
219	34044	064	084	104	124	143	163	183	203	223	2	4	6	8	10	12	14	16	18

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	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
220	34242	262	282	301	321	341	361	381	400	420	2	4	6	8	10	12	14	16	18
221	439	459	479	498	518	537	557	577	596	616	2	4	6	8	10	12	14	16	18
222	635	655	674	694	713	733	753	772	792	811	2	4	6	8	10	12	14	16	18
223	830	850	869	889	908	928	947	966	986	*005*	2	4	6	8	10	12	14	16	18
224	35025	044	064	083	102	122	141	160	180	199	2	4	6	8	10	12	14	15	17
225	218	238	257	276	295	315	334	353	372	392	2	4	6	8	10	12	14	15	17
226	411	430	449	468	488	507	526	545	564	583	2	4	6	8	10	12	13	15	17
227	603	622	641	660	679	698	717	736	755	774	2	4	6	8	10	11	13	15	17
228	793	813	832	851	870	889	908	927	946	965	2	4	6	8	10	11	13	15	17
229	984	*003*	*021*	*040*	*059*	*078*	*097*	*116*	*135*	*154*	2	4	6	8	9	11	13	15	17
230	36173	192	211	229	248	267	286	305	324	342	2	4	6	8	9	11	13	15	17
231	361	380	399	418	437	455	474	493	511	530	2	4	6	8	9	11	13	15	17
232	549	568	586	605	624	642	661	680	698	717	2	4	6	7	9	11	13	15	17
233	736	754	773	791	810	829	847	866	884	903	2	4	6	7	9	11	13	15	17
234	922	940	959	977	996	*014*	*033*	*051*	*070*	*088*	2	4	6	7	9	11	13	15	17
235	37107	125	144	162	181	200	218	236	254	273	2	4	6	7	9	11	13	15	17
236	291	310	328	346	365	383	401	420	438	457	2	4	6	7	9	11	13	15	16
237	475	493	511	530	548	566	585	603	621	639	2	4	5	7	9	11	13	15	16
238	658	676	694	712	731	749	767	785	803	822	2	4	5	7	9	11	13	15	16
239	840	858	876	894	912	931	949	967	985	*003*	2	4	5	7	9	11	13	14	16
240	38021	039	057	075	093	112	130	148	166	184	2	4	5	7	9	11	13	14	16
241	202	220	238	256	274	292	310	328	346	364	2	4	5	7	9	11	13	14	16
242	382	399	417	435	453	471	489	507	525	543	2	4	5	7	9	11	13	14	16
243	561	578	596	614	632	650	668	686	703	721	2	4	5	7	9	11	12	14	16
244	739	757	775	792	810	828	846	863	881	899	2	4	5	7	9	11	12	14	16
245	917	934	952	970	987	*005*	*023*	*041*	*058*	*076*	2	4	5	7	9	11	12	14	16
246	39094	111	129	146	164	182	199	217	235	252	2	4	5	7	9	11	12	14	16
247	270	287	305	322	340	358	375	393	410	428	2	4	5	7	9	11	12	14	16
248	445	463	480	498	515	533	550	568	585	602	2	3	5	7	9	10	12	14	16
249	620	637	655	672	690	707	724	742	759	777	2	3	5	7	9	10	12	14	16
250	794	811	829	846	863	881	898	915	933	950	2	3	5	7	9	10	12	14	16
251	967	985	*002*	*019*	*037*	*054*	*071*	*088*	*106*	*123*	2	3	5	7	9	10	12	14	16
252	40140	157	174	192	209	226	243	261	278	295	2	3	5	7	9	10	12	14	15
253	312	329	346	364	381	398	415	432	449	466	2	3	5	7	9	10	12	14	15
254	483	500	518	535	552	569	586	603	620	637	2	3	5	7	9	10	12	14	15
255	654	671	688	705	722	739	756	773	790	807	2	3	5	7	8	10	12	14	15
256	824	841	858	875	892	909	926	943	959	976	2	3	5	7	8	10	12	14	15
257	993	*010*	*027*	*044*	*061*	*078*	*095*	*111*	*128*	*145*	2	3	5	7	8	10	12	13	15
258	41162	179	196	212	229	246	263	280	296	313	2	3	5	7	8	10	12	13	15
259	330	347	363	380	397	414	430	447	464	481	2	3	5	7	8	10	12	13	15

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260	41497	514	531	547	554	581	597	614	631	647	2	3	5	7	8	10	12	13	15
261	664	680	697	714	731	747	764	781	797	814	2	3	5	7	8	10	12	13	15
262	830	847	863	880	896	913	929	946	963	979	2	3	5	7	8	10	12	13	15
263	996	*012*	*029*	*045*	*062*	*078*	*095*	*111*	*127*	*143*	2	3	5	7	8	10	12	13	15
264	42160	177	193	209	226	243	259	275	292	308	2	3	5	7	8	10	11	13	15
265	325	341	357	374	390	406	423	439	455	472	2	3	5	7	8	10	11	13	15
266	488	504	521	537	553	570	586	602	619	635	2	3	5	7	8	10	11	13	15
267	651	667	684	700	716	732	749	765	781	797	2	3	5	6	8	10	11	13	15
268	813	830	846	862	878	894	910	927	943	959	2	3	5	6	8	10	11	13	15
269	975	991	*008*	*024*	*040*	*056*	*072*	*088*	*104*	*120*	2	3	5	6	8	10	11	13	14
270	43136	152	169	185	201	217	233	249	265	281	2	3	5	6	8	10	11	13	14
271	297	313	329	345	361	377	393	409	425	441	2	3	5	6	8	10	11	13	14
272	457	473	489	505	521	537	553	569	585	600	2	3	5	6	8	10	11	13	14
273	616	632	648	664	680	696	712	727	743	759	2	3	5	6	8	10	11	13	14
274	775	791	807	823	838	854	870	886	902	917	2	3	5	6	8	10	11	13	14
275	933	949	965	981	996	*012*	*028*	*044*	*059*	*075*	2	3	5	6	8	9	11	13	14
276	44091	107	122	138	154	170	185	201	217	232	2	3	5	6	8	9	11	13	14
277	248	264	279	295	311	326	342	358	373	389	2	3	5	6	8	9	11	13	14
278	404	420	436	451	467	483	498	514	529	545	2	3	5	6	8	9	11	12	14
279	560	576	592	607	623	638	654	669	685	700	2	3	5	6	8	9	11	12	14
280	716	731	747	762	778	793	809	824	840	855	2	3	5	6	8	9	11	12	14
281	871	886	902	917	932	948	963	979	994	*010*	2	3	5	6	8	9	11	12	14
282	45025	040	056	071	086	102	117	133	148	163	2	3	5	6	8	9	11	12	14
283	179	194	209	225	240	255	271	286	301	317	2	3	5	6	8	9	11	12	14
284	332	347	362	378	393	408	423	439	454	469	2	3	5	6	8	9	11	12	14
285	484	500	515	530	545	560	576	591	606	621	2	3	5	6	8	9	11	12	14
286	637	652	667	682	697	712	728	743	758	773	2	3	5	6	8	9	11	12	14
287	788	803	818	834	849	864	879	894	909	924	2	3	5	6	8	9	11	12	14
288	939	954	969	984	*000*	*015*	*030*	*045*	*060*	*075*	2	3	5	6	8	9	11	12	14
289	46090	105	120	135	*150*	165	180	195	210	225	1	3	4	6	8	9	10	12	13
290	240	255	270	285	300	315	330	344	359	374	1	3	4	6	7	9	10	12	13
291	389	404	419	434	449	464	479	494	509	523	1	3	4	6	7	9	10	12	13
292	538	553	568	583	598	613	627	642	657	672	1	3	4	6	7	9	10	12	13
293	687	702	716	731	746	761	776	790	805	820	1	3	4	6	7	9	10	12	13
294	835	849	864	879	894	909	923	938	953	967	1	3	4	6	7	9	10	12	13
295	982	997	*012*	*026*	*041*	*056*	*070*	*085*	*100*	*114*	1	3	4	6	7	9	10	12	13
296	47129	144	159	173	188	202	217	232	246	261	1	3	4	6	7	9	10	12	13
297	276	290	305	319	334	349	363	378	392	407	1	3	4	6	7	9	10	12	13
298	422	436	451	466	480	494	509	524	538	553	1	3	4	6	7	9	10	12	13
299	567	582	596	611	625	640	654	669	683	698	1	3	4	6	7	9	10	12	13

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300	47712	727	741	756	770	784	799	813	828	842	1	3	4	6	7	9	10	12	13
301		857	871	885	900	914	929	943	958	972	986	1	3	4	6	7	9	10	12	13
302	48001	015	029	044	058	073	087	101	116	130	1	3	4	6	7	9	10	11	13
303	144	159	173	187	202	216	230	244	258	273	1	3	4	6	7	9	10	11	13
304	2.7	302	316	330	344	359	373	387	401	416	1	3	4	6	7	9	10	11	13
305	430	444	458	473	487	501	515	530	544	558	1	3	4	6	7	9	10	11	13
306	572	586	601	615	629	643	657	671	686	700	1	3	4	6	7	9	10	11	13
307	714	728	742	756	770	785	799	813	827	841	1	3	4	6	7	8	10	11	13
308	855	869	883	887	911	926	940	954	968	982	1	3	4	6	7	8	10	11	13
309	996	*010*	*024*	*038*	*052*	*066*	*080*	*094*	*108*	*122*	1	3	4	6	7	8	10	11	13
310	49136	150	164	178	192	206	220	234	248	262	1	3	4	6	7	8	10	11	13
311	276	290	304	318	332	346	360	374	388	402	1	3	4	6	7	8	10	11	13
312	415	429	443	457	471	485	499	513	527	541	1	3	4	6	7	8	10	11	13
313	554	568	582	596	610	624	638	651	665	679	1	3	4	6	7	8	10	11	12
314	693	707	721	734	748	762	776	790	803	817	1	3	4	6	7	8	10	11	12
315	831	845	859	872	886	900	914	927	941	955	1	3	4	5	7	8	10	11	12
316	969	983	996	*010*	*024*	*037*	*051*	*065*	*079*	*092*	1	3	4	5	7	8	10	11	12
317	50106	119	133	147	161	174	188	202	215	229	1	3	4	5	7	8	10	11	12
318	243	256	270	284	297	311	325	338	352	365	1	3	4	5	7	8	10	11	12
319	379	393	407	420	433	447	461	474	488	501	1	3	4	5	7	8	10	11	12
320	515	529	542	556	569	583	596	610	624	637	1	3	4	5	7	8	9	11	12
321	650	664	678	691	705	718	732	745	759	772	1	3	4	5	7	8	9	11	12
322	786	799	813	826	839	853	866	880	893	907	1	3	4	5	7	8	9	11	12
323	920	934	947	961	974	987	*001*	*014*	*028*	*041*	1	3	4	5	7	8	9	11	12
324	51054	068	081	095	108	121	135	148	161	175	1	3	4	5	7	8	9	11	12
325	188	202	215	228	242	255	268	282	295	308	1	3	4	5	7	8	9	11	12
326	322	335	348	362	375	388	402	415	428	442	1	3	4	5	7	8	9	11	12
327	455	468	481	495	508	521	534	548	561	574	1	3	4	5	7	8	9	11	12
328	587	601	614	627	640	654	667	680	693	706	1	3	4	5	7	8	9	11	12
329	720	733	746	759	772	786	799	812	825	838	1	3	4	5	7	8	9	11	12
330	851	865	878	891	904	917	930	943	957	970	1	3	4	5	7	8	9	11	12
331	983	996	*009*	*022*	*035*	*048*	*061*	*075*	*088*	*101*	1	3	4	5	7	8	9	10	12
332	52114	127	140	153	166	179	192	205	218	231	1	3	4	5	7	8	9	10	12
333	244	257	270	284	297	310	323	336	349	362	1	3	4	5	7	8	9	10	12
334	375	388	401	414	427	440	453	466	479	492	1	3	4	5	6	8	9	10	12
335	504	517	530	543	556	569	582	595	608	621	1	3	4	5	6	8	9	10	12
336	634	647	660	673	686	699	711	724	737	750	1	3	4	5	6	8	9	10	12
337	763	776	789	802	815	827	840	853	866	879	1	3	4	5	6	8	9	10	12
338	892	905	917	930	943	956	969	982	994	*007*	1	3	4	5	6	8	9	10	12
339	53020	033	046	058	071	084	097	110	122	135	1	3	4	5	6	8	9	10	12

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340	53148	161	173	186	199	212	224	237	250	263	1	3	4	5	6	8	9	10	11
341	275	288	301	314	326	339	352	364	377	390	1	3	4	5	6	8	9	10	11
342	403	415	428	441	453	466	479	491	504	517	1	3	4	5	6	8	9	10	11
343	529	542	555	567	580	593	605	618	631	643	1	3	4	5	6	8	9	10	11
344	655	668	681	694	706	719	732	744	757	769	1	3	4	5	6	8	9	10	11
345	782	794	807	820	832	845	857	870	882	895	1	3	4	5	6	8	9	10	11
346	908	920	933	945	958	970	983	995	*008*	*020*	1	3	4	5	6	8	9	10	11
347	54033	045	058	070	083	095	108	120	133	145	1	2	4	5	6	8	9	10	11
348	158	170	183	195	208	220	233	245	258	270	1	2	4	5	6	7	9	10	11
349	283	295	308	320	332	345	357	370	382	394	1	2	4	5	6	7	9	10	11
350	407	419	432	444	456	469	481	494	506	518	1	2	4	5	6	7	9	10	11
351	531	543	555	568	580	593	605	617	630	642	1	2	4	5	6	7	9	10	11
352	654	667	679	691	704	716	728	741	753	765	1	2	4	5	6	7	9	10	11
353	777	790	802	814	827	839	851	864	876	888	1	2	4	5	6	7	9	10	11
354	900	913	925	937	949	962	974	986	998	*011*	1	2	4	5	6	7	9	10	11
355	55023	035	047	060	072	084	096	108	121	133	1	2	4	5	6	7	9	10	11
356	145	157	169	182	194	206	218	230	242	255	1	2	4	5	6	7	9	10	11
357	267	279	291	303	315	328	340	352	364	376	1	2	4	5	6	7	9	10	11
358	388	400	413	425	437	449	461	473	485	497	1	2	4	5	6	7	8	10	11
359	509	522	534	546	558	570	582	594	606	618	1	2	4	5	6	7	8	10	11
360	630	642	654	666	678	691	703	715	727	739	1	2	4	5	6	7	8	10	11
361	751	763	775	787	799	811	823	835	847	859	1	2	4	5	6	7	8	10	11
362	871	883	895	907	919	931	943	955	967	979	1	2	4	5	6	7	8	10	11
363	991	*003*	*015*	*027*	*038*	*050*	*062*	*074*	*086*	*098*	1	2	4	5	6	7	8	10	11
364	56110	122	134	146	158	170	182	194	205	217	1	2	4	5	6	7	8	10	11
365	229	241	253	265	277	289	301	312	324	336	1	2	4	5	6	7	8	10	11
366	348	360	372	384	396	407	419	431	443	455	1	2	4	5	6	7	8	9	10
367	467	478	490	502	514	526	538	549	561	573	1	2	4	5	6	7	8	9	10
368	585	597	608	620	632	644	656	667	679	691	1	2	4	5	6	7	8	9	10
369	703	714	726	738	750	761	773	785	797	808	1	2	4	5	6	7	8	9	10
370	820	832	844	855	867	879	891	902	914	926	1	2	4	5	6	7	8	9	10
371	937	949	961	972	984	996	*008*	*019*	*031*	*043*	1	2	4	5	6	7	8	9	10
372	57054	066	078	089	101	113	124	136	148	159	1	2	3	5	6	7	8	9	10
373	171	183	194	206	217	229	241	252	264	276	1	2	3	5	6	7	8	9	10
374	287	299	310	322	334	345	357	368	380	392	1	2	3	5	6	7	8	9	10
375	403	415	426	438	449	461	473	484	496	507	1	2	3	5	6	7	8	9	10
376	519	530	542	553	565	576	588	600	611	623	1	2	3	5	6	7	8	9	10
377	634	646	657	669	680	692	703	715	726	738	1	2	3	5	6	7	8	9	10
378	749	761	772	784	795	807	818	830	841	852	1	2	3	5	6	7	8	9	10
379	864	875	887	898	910	921	933	944	955	967	1	2	3	5	6	7	8	9	10

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380	57978	990	*001*	*013*	*024*	*035*	*047*	*058*	*070*	*081*	1	2	3	5	6	7	8	9	10
381	58092	104	115	127	138	149	161	172	184	195	1	2	3	5	6	7	8	9	10
382	206	218	229	240	252	263	274	286	297	309	1	2	3	5	6	7	8	9	10
383	320	331	343	354	365	377	388	399	410	422	1	2	3	5	6	7	8	9	10
384	433	444	456	467	478	490	501	512	524	535	1	2	3	5	6	7	8	9	10
385	545	557	569	580	591	602	614	625	636	647	1	2	3	4	6	7	8	9	10
386	659	670	681	692	704	715	726	737	749	760	1	2	3	4	6	7	8	9	10
387	771	782	794	805	816	827	838	850	861	872	1	2	3	4	6	7	8	9	10
388	883	894	906	917	928	939	950	961	973	984	1	2	3	4	6	7	8	9	10
389	995	*006*	*017*	*028*	*040*	*051*	*062*	*073*	*084*	*095*	1	2	3	4	6	7	8	9	10
390	59106	118	129	140	151	162	173	184	195	207	1	2	3	4	6	7	8	9	10
391	218	229	240	251	262	273	284	295	306	318	1	2	3	4	6	7	8	9	10
392	329	340	351	362	373	384	395	406	417	428	1	2	3	4	6	7	8	9	10
393	439	450	461	472	483	494	506	517	528	539	1	2	3	4	6	7	8	9	10
394	550	561	572	583	594	605	616	627	638	649	1	2	3	4	5	7	8	9	10
395	660	671	682	693	704	715	726	737	748	759	1	2	3	4	5	7	8	9	10
396	770	780	791	802	813	824	835	846	857	868	1	2	3	4	5	7	8	9	10
397	879	890	901	912	923	934	945	956	966	977	1	2	3	4	5	7	8	9	10
398	988	999	*010*	*021*	*032*	*043*	*054*	*065*	*076*	*086*	1	2	3	4	5	7	8	9	10
399	60097	108	119	130	141	152	163	173	184	195	1	2	3	4	5	7	8	9	10
400	206	217	228	239	249	260	271	282	293	304	1	2	3	4	5	7	8	9	10
401	314	325	336	347	358	369	379	390	401	412	1	2	3	4	5	6	8	9	10
402	423	433	444	455	466	477	487	498	509	520	1	2	3	4	5	6	8	9	10
403	530	541	552	563	574	584	595	606	617	627	1	2	3	4	5	6	8	9	10
404	638	649	660	670	681	692	703	713	724	735	1	2	3	4	5	6	8	9	10
405	745	756	767	778	788	799	810	820	831	842	1	2	3	4	5	6	7	9	10
406	853	863	874	885	895	906	917	927	938	949	1	2	3	4	5	6	7	9	10
407	959	970	981	991	*002*	*013*	*023*	*034*	*045*	*055*	1	2	3	4	5	6	7	9	10
408	61066	077	087	098	109	119	130	140	151	162	1	2	3	4	5	6	7	9	10
409	172	183	194	204	215	225	236	247	257	268	1	2	3	4	5	6	7	8	10
410	278	289	299	310	321	331	342	352	363	374	1	2	3	4	5	6	7	8	10
411	384	395	405	416	426	437	448	458	469	479	1	2	3	4	5	6	7	8	10
412	490	500	511	521	532	542	553	563	574	584	1	2	3	4	5	6	7	8	9
413	595	606	616	627	637	648	658	669	679	690	1	2	3	4	5	6	7	8	9
414	700	711	721	732	742	752	763	773	784	794	1	2	3	4	5	6	7	8	9
415	805	815	826	836	847	857	868	878	888	899	1	2	3	4	5	6	7	8	9
416	909	920	930	941	951	961	972	982	993	*003*	1	2	3	4	5	6	7	8	9
417	62014	024	034	045	055	065	076	086	097	107	1	2	3	4	5	6	7	8	9
418	118	128	138	149	159	170	180	190	201	211	1	2	3	4	5	6	7	8	9
419	221	232	242	252	263	273	284	294	304	315	1	2	3	4	5	6	7	8	9

420 Five-figure Logarithms—*continued.* [·62

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
420	62325	335	346	356	366	377	387	397	408	418	1	2	3	4	5	6	7	8	9
421	428	439	449	459	469	480	490	500	511	521	1	2	3	4	5	6	7	8	9
422	531	542	552	562	572	583	593	603	613	624	1	2	3	4	5	6	7	8	9
423	634	644	655	665	675	685	696	706	716	726	1	2	3	4	5	6	7	8	9
424	737	747	757	767	778	788	798	808	818	829	1	2	3	4	5	6	7	8	9
425	839	849	859	870	880	890	900	910	921	931	1	2	3	4	5	6	7	8	9
426	941	951	961	972	982	992	*002*	*012*	*022*	*033*	1	2	3	4	5	6	7	8	9
427	63043	053	063	073	083	094	104	114	124	134	1	2	3	4	5	6	7	8	9
428	144	155	165	175	185	195	205	215	225	236	1	2	3	4	5	6	7	8	9
429	246	256	266	276	286	296	306	317	327	337	1	2	3	4	5	6	7	8	9
430	347	357	367	377	387	397	407	417	428	438	1	2	3	4	5	6	7	8	9
431	448	458	468	478	488	498	508	518	528	538	1	2	3	4	5	6	7	8	9
432	548	558	568	579	589	599	609	619	629	639	1	2	3	4	5	6	7	8	9
433	649	659	669	679	689	699	709	719	729	739	1	2	3	4	5	6	7	8	9
434	749	759	769	779	789	799	809	819	829	839	1	2	3	4	5	6	7	8	9
435	849	859	869	879	889	899	909	919	929	939	1	2	3	4	5	6	7	8	9
436	949	959	969	979	988	998	*008*	*018*	*028*	*038*	1	2	3	4	5	6	7	8	9
437	64048	058	068	078	088	098	108	118	128	137	1	2	3	4	5	6	7	8	9
438	147	157	167	177	187	197	207	217	227	237	1	2	3	4	5	6	7	8	9
439	246	256	266	276	286	296	306	316	326	335	1	2	3	4	5	6	7	8	9
440	345	355	365	375	385	395	404	414	424	434	1	2	3	4	5	6	7	8	9
441	444	454	464	473	483	493	503	513	523	532	1	2	3	4	5	6	7	8	9
442	542	552	562	572	582	591	601	611	621	631	1	2	3	4	5	6	7	8	9
443	640	650	660	670	680	689	699	709	719	729	1	2	3	4	5	6	7	8	9
444	738	748	758	768	777	787	797	807	816	826	1	2	3	4	5	6	7	8	9
445	836	846	856	865	875	885	895	904	914	924	1	2	3	4	5	6	7	8	9
446	933	943	953	963	972	982	992	*002*	*011*	*021*	1	2	3	4	5	6	7	8	9
447	65031	040	050	060	070	079	089	099	108	118	1	2	3	4	5	6	7	8	9
448	128	137	147	157	167	176	186	196	205	215	1	2	3	4	5	6	7	8	9
449	225	234	244	254	263	273	283	292	302	312	1	2	3	4	5	6	7	8	9
450	321	331	341	350	360	369	379	388	398	408	1	2	3	4	5	6	7	8	9
451	418	428	437	447	456	466	475	485	495	504	1	2	3	4	5	6	7	8	9
452	514	523	533	543	552	562	571	581	591	600	1	2	3	4	5	6	7	8	9
453	610	619	629	639	648	657	667	676	686	696	1	2	3	4	5	6	7	8	9
454	706	715	725	734	744	753	763	772	782	792	1	2	3	4	5	6	7	8	9
455	801	811	820	830	839	849	858	868	877	887	1	2	3	4	5	6	7	8	9
456	896	906	916	925	935	944	954	963	973	982	1	2	3	4	5	6	7	8	9
457	992	*001*	*011*	*020*	*030*	*039*	*049*	*058*	*068*	077	1	2	3	4	5	6	7	8	9
458	66087	096	106	115	124	134	144	153	162	172	1	2	3	4	5	6	7	8	9
459	181	191	200	210	219	229	238	247	257	256	1	2	3	4	5	6	7	8	9

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467	932	941	950	960	969	978	987	996	*006*	*015*	1	2	3	4	5	6	6	7	8
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476	761	770	779	788	797	806	815	825	834	843	1	2	3	4	5	5	6	7	8
477	852	861	870	879	888	897	906	915	925	934	1	2	3	4	5	5	6	7	8
478	943	952	961	970	979	988	997	*006*	*015*	*024*	1	2	3	4	5	5	6	7	8
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485	574	583	592	601	610	619	628	637	646	655	1	2	3	4	4	5	6	7	8
486	664	673	681	690	699	708	717	726	735	744	1	2	3	4	4	5	6	7	8
487	753	762	771	780	789	797	806	815	824	833	1	2	3	4	4	5	6	7	8
488	842	851	860	869	878	886	895	904	913	922	1	2	3	4	4	5	6	7	8
489	931	940	949	958	966	975	984	993	*002*	*011*	1	2	3	4	4	5	6	7	8
490	69020	028	037	046	055	064	073	082	090	099	1	2	3	4	4	5	6	7	8
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492	197	205	214	223	232	241	249	258	267	276	1	2	3	4	4	5	6	7	8
493	285	293	302	311	320	329	338	346	355	364	1	2	3	4	4	5	6	7	8
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497	636	644	653	662	671	679	688	697	705	714	1	2	3	3	4	5	6	7	8
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501	984	992	*001*	*010*	*018*	*027*	*036*	*044*	*053*	*062*	1	2	3	3	4	5	6	7	8
502	70070	079	088	096	105	114	122	131	140	148	1	2	3	3	4	5	6	7	8
503	157	165	174	183	191	200	209	217	226	234	1	2	3	3	4	5	6	7	8
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515	181	189	198	206	214	223	231	240	248	257	1	2	3	3	4	5	6	7	8
516	265	273	282	290	299	307	315	324	332	341	1	2	3	3	4	5	6	7	8
517	349	357	366	374	383	391	399	408	416	425	1	2	3	3	4	5	6	7	8
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524	933	941	950	958	966	975	983	991	999	*008*	1	2	2	3	4	5	6	7	7
525	72016	024	032	041	049	057	066	074	082	090	1	2	2	3	4	5	6	7	7
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530	428	436	444	452	460	469	477	485	493	501	1	2	2	3	4	5	6	7	7
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538	73078	086	094	102	111	119	127	135	143	151	1	2	2	3	4	5	6	6	7
539	159	167	175	183	191	199	207	215	223	231	1	2	2	3	4	5	6	6	7

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540	73239	247	255	264	**272**	280	288	296	304	312	1	2	2	3	4	5	6	6	7
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546	719	727	735	743	751	759	767	775	783	791	1	2	2	3	4	5	6	6	7
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550	74036	044	052	060	068	076	084	092	099	107	1	2	2	3	4	5	6	6	7
551	115	123	131	139	147	155	162	170	178	186	1	2	2	3	4	5	6	6	7
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555	429	437	445	453	461	468	476	484	492	500	1	2	2	3	4	5	5	6	7
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564	128	136	143	151	159	166	174	182	189	197	1	2	2	3	4	5	5	6	7
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575	967	974	982	989	997	*005*	*012*	*020*	*027*	*035*	1	2	2	3	4	5	5	6	7
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603	78032	039	046	053	061	068	075	082	089	096	1	1	2	3	4	4	5	6	6
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605	176	183	190	197	204	211	219	226	233	240	1	1	2	3	4	4	5	6	6
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615	888	895	902	909	916	923	930	937	944	951	1	1	2	3	4	4	5	6	6
616	958	965	972	979	986	993	*000*	*007*	*014*	*021*	1	1	2	3	4	4	5	6	6
617	79029	036	043	050	057	064	071	078	085	092	1	1	2	3	4	4	5	6	6
618	099	106	113	120	127	134	141	148	155	162	1	1	2	3	4	4	5	6	6
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637	414	421	428	434	441	448	455	462	468	475	1	1	2	3	3	4	5	5	6
638	482	489	496	502	509	516	523	530	536	543	1	1	2	3	3	4	5	5	6
639	550	557	564	570	577	584	591	598	604	611	1	1	2	3	3	4	5	5	6
640	618	625	632	638	645	652	659	665	672	679	1	1	2	3	3	4	5	5	6
641	686	693	699	706	713	720	726	733	740	747	1	1	2	3	3	4	5	5	6
642	754	760	767	774	781	787	794	801	808	814	1	1	2	3	3	4	5	5	6
643	821	828	835	841	848	855	862	868	875	882	1	1	2	3	3	4	5	5	6
644	889	895	902	909	916	922	929	936	942	949	1	1	2	3	3	4	5	5	6
645	956	963	969	976	983	990	996	*003*	*010*	*017*	1	1	2	3	3	4	5	5	6
646	81023	030	037	043	050	057	064	070	077	084	1	1	2	3	3	4	5	5	6
647	090	097	104	111	117	124	131	137	144	151	1	1	2	3	3	4	5	5	6
648	158	164	171	178	184	191	198	204	211	218	1	1	2	3	3	4	5	5	6
649	224	231	238	245	251	258	265	271	278	285	1	1	2	3	3	4	5	5	6
650	291	298	305	311	318	325	331	338	345	351	1	1	2	3	3	4	5	5	6
651	358	365	371	378	385	391	398	405	411	418	1	1	2	3	3	4	5	5	6
652	425	431	438	445	451	458	465	471	478	485	1	1	2	3	3	4	5	5	6
653	491	498	505	511	518	525	531	538	*544*	551	1	1	2	3	3	4	5	5	6
654	558	564	571	578	584	591	598	604	611	618	1	1	2	3	3	4	5	5	6
655	624	631	637	644	651	657	664	671	677	684	1	1	2	3	3	4	5	5	6
656	690	697	704	710	717	723	730	737	743	750	1	1	2	3	3	4	5	5	6
657	757	763	770	776	783	790	796	803	809	816	1	1	2	3	3	4	5	5	6
658	823	829	836	842	849	856	862	869	875	882	1	1	2	3	3	4	5	5	6
659	889	895	902	908	915	921	928	935	941	948	1	1	2	3	3	4	5	5	6

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
660	81954	961	968	974	981	987	994	*000*	*007*	*014*	1	1	2	3	3	4	5	5	6
661	82020	027	033	040	046	053	060	066	073	079	1	1	2	3	3	4	5	5	6
662	086	092	099	105	112	119	125	132	138	145	1	1	2	3	3	4	5	5	6
563	151	158	164	171	177	184	191	197	204	210	1	1	2	3	3	4	5	5	6
564	217	223	230	236	243	250	256	263	269	276	1	1	2	3	3	4	5	5	6
665	282	289	295	302	308	315	321	328	334	341	1	1	2	3	3	4	5	5	6
666	347	354	360	367	374	380	387	393	400	406	1	1	2	3	3	4	5	5	6
667	413	419	426	432	439	445	452	458	465	471	1	1	2	3	3	4	5	5	6
668	478	484	491	497	504	510	517	523	530	536	1	1	2	3	3	4	5	5	6
669	543	549	556	562	569	575	582	588	595	601	1	1	2	3	3	4	5	5	6
670	607	614	620	627	633	640	646	653	659	666	1	1	2	3	3	4	5	5	6
671	672	679	685	692	698	705	711	718	724	730	1	1	2	3	3	4	5	5	6
672	737	743	750	756	762	769	776	782	789	795	1	1	2	3	3	4	5	5	6
673	802	808	814	821	827	834	840	847	853	860	1	1	2	3	3	4	5	5	6
674	866	872	879	885	892	898	905	911	918	924	1	1	2	3	3	4	4	5	6
675	930	937	943	95)	956	963	969	975	982	988	1	1	2	3	3	4	4	5	6
676	995	*001*	*008*	*014*	*020*	*027*	*033*	*040*	*046*	*052*	1	1	2	3	3	4	4	5	6
677	83059	065	072	078	085	091	097	104	110	117	1	1	2	3	3	4	4	5	6
678	123	129	136	142	149	155	161	168	174	181	1	1	2	3	3	4	4	5	6
679	187	193	200	206	213	219	225	232	238	244	1	1	2	3	3	4	4	5	6
680	251	257	264	270	276	283	289	296	302	308	1	1	2	3	3	4	4	5	6
681	315	321	327	334	340	347	353	359	366	372	1	1	2	3	3	4	4	5	6
682	378	385	391	398	404	410	417	423	429	436	1	1	2	3	3	4	4	5	6
683	442	448	455	461	468	474	480	487	493	499	1	1	2	3	3	4	4	5	6
684	506	512	518	525	531	537	544	550	556	563	1	1	2	3	3	4	5	5	6
685	569	575	582	588	594	601	607	613	620	626	1	1	2	3	3	4	5	5	6
686	632	639	645	651	658	664	670	677	683	689	1	1	2	3	3	4	4	5	6
687	696	702	708	715	721	727	734	740	746	753	1	1	2	3	3	4	4	5	6
688	759	765	771	778	784	790	797	803	809	816	1	1	2	3	3	4	4	5	6
689	822	828	835	841	847	853	860	866	872	879	1	1	2	3	3	4	5	5	6
690	885	891	898	904	910	916	923	929	935	942	1	1	2	3	3	4	4	5	6
691	948	954	960	967	973	979	986	992	998	*004*	1	1	2	3	3	4	4	5	6
692	84011	017	023	029	036	042	048	055	061	067	1	1	2	3	3	4	4	5	6
693	073	080	086	092	098	105	111	117	123	130	1	1	2	2	3	4	4	5	6
694	136	142	148	155	161	167	173	180	186	192	1	1	2	2	3	4	4	5	6
695	198	205	211	217	223	230	236	242	248	255	1	1	2	2	3	4	4	5	6
696	261	267	273	280	286	292	298	305	311	317	1	1	2	2	3	4	4	5	6
697	323	330	336	342	348	354	361	367	373	379	1	1	2	2	3	4	4	5	6
698	386	392	398	404	410	417	423	429	435	442	1	1	2	2	3	4	4	5	6
699	448	454	460	466	473	479	485	491	497	504	1	1	2	2	3	4	4	5	6

700] Five-figure Logarithms—*continued.* ['84

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
700	84510	516	522	528	535	541	547	553	559	566	1	1	2	2	3	4	4	5	6
701	572	578	584	590	597	603	609	615	621	628	1	1	2	2	3	4	4	5	6
702	634	640	646	652	658	665	671	677	683	689	1	1	2	2	3	4	4	5	6
703	696	702	708	714	720	726	733	739	745	751	1	1	2	2	3	4	4	5	6
704	757	763	770	776	782	788	794	800	807	813	1	1	2	2	3	4	4	5	6
705	819	825	831	837	844	850	856	862	868	874	1	1	2	2	3	4	4	5	6
706	880	887	893	899	905	911	917	924	930	936	1	1	2	2	3	4	4	5	6
707	942	948	954	960	967	973	979	985	991	997	1	1	2	2	3	4	4	5	6
708	85003	009	016	022	028	034	040	046	052	058	1	1	2	2	3	4	4	5	6
709	065	071	077	083	089	095	101	107	114	120	1	1	2	2	3	4	4	5	6
710	126	132	138	144	150	156	163	169	175	181	1	1	2	2	3	4	4	5	6
711	187	193	199	205	211	217	224	230	236	242	1	1	2	2	3	4	4	5	5
712	248	254	260	266	272	278	285	291	297	303	1	1	2	2	3	4	4	5	5
713	309	315	321	327	333	339	345	352	358	364	1	1	2	2	3	4	4	5	5
714	370	376	382	388	394	400	406	412	418	425	1	1	2	2	3	4	4	5	5
715	431	437	443	449	455	461	467	473	479	485	1	1	2	2	3	4	4	5	5
716	491	497	503	510	516	522	528	534	540	546	1	1	2	2	3	4	4	5	5
717	552	558	564	570	576	582	588	594	600	606	1	1	2	2	3	4	4	5	5
718	612	618	625	631	637	643	649	655	661	667	1	1	2	2	3	4	4	5	5
719	673	679	685	691	697	703	709	715	721	727	1	1	2	2	3	4	4	5	5
720	733	739	745	751	757	763	769	775	781	788	1	1	2	2	3	4	4	5	5
721	794	800	806	812	818	824	830	836	842	848	1	1	2	2	3	4	4	5	5
722	854	860	866	872	878	884	890	896	902	908	1	1	2	2	3	4	4	5	5
723	914	920	926	932	938	944	950	956	962	968	1	1	2	2	3	4	4	5	5
724	974	980	986	992	998	*004*	*010*	*016*	*022*	*028*	1	1	2	2	3	4	4	5	5
725	86034	040	046	052	058	064	070	076	082	088	1	1	2	2	3	4	4	5	5
726	094	100	106	112	118	124	130	136	141	147	1	1	2	2	3	4	4	5	5
727	153	159	165	171	177	183	189	195	201	207	1	1	2	2	3	4	4	5	5
728	213	219	225	231	237	243	249	255	261	267	1	1	2	2	3	4	4	5	5
729	273	279	285	291	297	303	308	314	320	326	1	1	2	2	3	4	4	5	5
730	332	338	344	350	356	362	368	374	380	386	1	1	2	2	3	4	4	5	5
731	392	398	404	410	416	421	427	433	439	445	1	1	2	2	3	4	4	5	5
732	451	457	463	469	475	481	487	493	499	504	1	1	2	2	3	4	4	5	5
733	510	516	522	528	534	540	546	552	558	564	1	1	2	2	3	4	4	5	5
734	570	576	581	587	593	599	605	611	617	623	1	1	2	2	3	4	4	5	5
735	629	635	641	646	652	658	664	670	676	682	1	1	2	2	3	4	4	5	5
736	688	694	700	705	711	717	723	729	735	741	1	1	2	2	3	4	4	5	5
737	747	753	759	764	770	776	782	788	794	800	1	1	2	2	3	4	4	5	5
738	806	812	817	823	829	835	841	847	853	859	1	1	2	2	3	4	4	5	5
739	864	870	876	882	888	894	900	906	911	917	1	1	2	2	3	4	4	5	5

740] Five-figure Logarithms—*continued.* **[·86**

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
740	86923	929	935	941	947	953	958	964	970	976	1	1	2	2	3	4	4	5	5
741	982	988	994	999	*005*	*011*	*017*	*023*	*029*	*035*	1	1	2	2	3	4	4	5	5
742	87040	046	052	058	064	070	075	081	087	093	1	1	2	2	3	4	4	5	5
743	099	105	111	116	122	128	134	140	146	151	1	1	2	2	3	4	4	5	5
744	157	163	169	175	181	186	192	198	204	210	1	1	2	2	3	4	4	5	5
745	216	221	227	233	239	245	251	256	262	268	1	1	2	2	3	3	4	5	5
746	274	280	286	291	297	303	309	315	320	326	1	1	2	2	3	3	4	5	5
747	332	338	344	350	355	361	367	373	379	384	1	1	2	2	3	3	4	5	5
748	390	396	402	408	413	419	425	431	437	442	1	1	2	2	3	3	4	5	5
749	448	454	460	466	471	477	483	489	495	500	1	1	2	2	3	3	4	5	5
750	506	512	518	523	529	535	541	547	552	558	1	1	2	2	3	3	4	5	5
751	564	570	576	581	587	593	599	604	610	616	1	1	2	2	3	3	4	5	5
752	622	628	633	639	645	651	656	662	668	674	1	1	2	2	3	3	4	5	5
753	680	685	691	697	703	708	714	720	726	731	1	1	2	2	3	3	4	5	5
754	737	743	749	754	760	766	772	777	783	789	1	1	2	2	3	3	4	5	5
755	795	800	806	812	818	823	829	835	841	846	1	1	2	2	3	3	4	5	5
756	852	858	864	869	875	881	887	892	898	904	1	1	2	2	3	3	4	5	5
757	910	915	921	927	933	938	944	950	955	961	1	1	2	2	3	3	4	5	5
758	967	973	978	984	990	996	*001*	*007*	*013*	*018*	1	1	2	2	3	3	4	5	5
759	88024	030	036	041	047	053	058	064	070	076	1	1	2	2	3	3	4	5	5
760	082	087	093	098	104	110	116	121	127	133	1	1	2	2	3	4	4	5	5
761	138	144	150	156	161	167	173	178	184	190	1	1	2	2	3	4	4	5	5
762	196	201	207	213	218	224	230	235	241	247	1	1	2	2	3	3	4	5	5
763	252	258	264	270	275	281	287	292	298	304	1	1	2	2	3	3	4	5	5
764	309	315	321	326	332	338	343	349	355	360	1	1	2	2	3	3	4	5	5
765	366	372	378	383	389	395	400	406	412	417	1	1	2	2	3	3	4	5	5
766	423	429	434	440	446	451	457	463	468	474	1	1	2	2	3	3	4	5	5
767	480	485	491	497	502	508	514	519	525	530	1	1	2	2	3	3	4	5	5
768	536	542	547	553	559	564	570	576	581	587	1	1	2	2	3	3	4	5	5
769	593	598	604	610	615	621	627	632	638	643	1	1	2	2	3	3	4	5	5
770	649	655	660	666	672	677	683	689	694	700	1	1	2	2	3	3	4	5	5
771	705	711	717	722	728	734	739	745	750	756	1	1	2	2	3	3	4	5	5
772	762	767	773	779	784	790	795	801	807	812	1	1	2	2	3	3	4	4	5
773	818	824	829	835	840	846	852	857	863	868	1	1	2	2	3	3	4	4	5
774	874	880	885	891	897	902	908	913	919	925	1	1	2	2	3	3	4	4	5
775	930	936	941	947	953	958	964	969	975	981	1	1	2	2	3	3	4	4	5
776	986	992	997	*003*	*009*	*014*	*020*	*025*	*031*	*037*	1	1	2	2	3	3	4	4	5
777	89042	048	053	059	064	070	076	081	087	092	1	1	2	2	3	3	4	4	5
778	098	104	109	115	120	126	131	137	143	148	1	1	2	2	3	3	4	4	5
779	154	159	165	170	176	182	187	193	198	204	1	1	2	2	3	3	4	4	5

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
780	89209	215	221	226	232	237	243	248	254	260	1	1	2	2	3	3	4	4	5
781	265	271	276	282	287	293	298	304	310	315	1	1	2	2	3	3	4	4	5
782	321	326	332	337	343	348	354	360	365	371	1	1	2	2	3	3	4	4	5
783	376	382	387	393	398	404	409	415	421	426	1	1	2	2	3	3	4	4	5
784	432	437	443	448	454	459	465	470	476	481	1	1	2	2	3	3	4	4	5
785	487	493	498	504	509	515	520	526	531	537	1	1	2	2	3	3	4	4	5
786	542	548	553	559	564	570	575	581	586	592	1	1	2	2	3	3	4	4	5
787	597	603	609	614	620	625	631	636	642	647	1	1	2	2	3	3	4	4	5
788	653	658	664	669	675	680	686	691	697	702	1	1	2	2	3	3	4	4	5
789	708	713	719	724	730	735	741	746	752	757	1	1	2	2	3	3	4	4	5
790	763	768	774	779	785	790	796	801	807	812	1	1	2	2	3	3	4	4	5
791	818	823	829	834	840	845	851	856	862	867	1	1	2	2	3	3	4	4	5
792	873	878	883	889	894	900	905	911	916	922	1	1	2	2	3	3	4	4	5
793	927	933	938	944	949	955	960	966	971	977	1	1	2	2	3	3	4	4	5
794	982	988	993	998	*004*	*009*	*015*	*020*	*026*	*031*	1	1	2	2	3	3	4	4	5
795	90037	042	048	053	059	064	069	075	080	086	1	1	2	2	3	3	4	4	5
796	091	097	102	108	113	119	124	129	135	140	1	1	2	2	3	3	4	4	5
797	146	151	157	162	168	173	179	184	189	195	1	1	2	2	3	3	4	4	5
798	200	206	211	217	222	227	233	238	244	249	1	1	2	2	3	3	4	4	5
799	255	260	266	271	276	282	287	293	298	304	1	1	2	2	3	3	4	4	5
800	309	314	320	325	331	336	342	347	352	358	1	1	2	2	3	3	4	4	5
801	363	369	374	380	385	390	396	401	407	412	1	1	2	2	3	3	4	4	5
802	417	423	428	434	439	444	450	455	461	466	1	1	2	2	3	3	4	4	5
803	472	477	482	488	493	499	504	509	**515**	**520**	1	1	2	2	3	3	4	4	5
804	526	531	536	542	547	553	558	563	569	574	1	1	2	2	3	3	4	4	5
805	580	585	590	596	601	607	612	617	623	628	1	1	2	2	3	3	4	4	5
806	634	639	644	650	655	660	666	671	677	682	1	1	2	2	3	3	4	4	5
807	687	693	698	704	709	714	720	725	730	736	1	1	2	2	3	3	4	4	5
808	741	747	752	757	763	768	773	779	784	789	1	1	2	2	3	3	4	4	5
809	795	800	806	811	816	822	827	832	838	843	1	1	2	2	3	3	4	4	5
810	849	854	859	865	870	875	881	886	891	897	1	1	2	2	3	3	4	4	5
811	902	907	913	918	924	929	934	940	945	950	1	1	2	2	3	3	4	4	5
812	956	961	966	972	977	982	988	993	998	*004*	1	1	2	2	3	3	4	4	5
813	91009	014	020	025	030	035	041	046	052	057	1	1	2	2	3	3	4	4	5
814	062	068	073	078	084	089	094	100	105	110	1	1	2	2	3	3	4	4	5
815	116	121	126	132	137	142	148	153	158	164	1	1	2	2	3	3	4	4	5
816	169	174	180	185	190	196	201	206	212	217	1	1	2	2	3	3	4	4	5
817	222	228	233	238	243	249	254	259	265	270	1	1	2	2	3	3	4	4	5
818	275	281	286	291	297	302	307	312	318	323	1	1	2	2	3	3	4	4	5
819	328	334	339	344	350	355	360	**365**	**371**	376	1	1	2	2	3	3	4	4	5

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
820	91381	387	392	397	403	408	413	418	424	429	1	1	2	2	3	3	4	4	5
821	434	440	445	450	455	461	466	471	477	482	1	1	2	2	3	3	4	4	5
822	487	492	498	503	508	514	519	524	529	535	1	1	2	2	3	3	4	4	5
823	540	545	551	556	561	566	572	577	582	587	1	1	2	2	3	3	4	4	5
824	593	598	603	609	614	619	624	630	635	640	1	1	2	2	3	3	4	4	5
825	645	651	656	661	666	672	677	682	687	693	1	1	2	2	3	3	4	4	5
826	698	703	709	714	719	724	730	735	740	745	1	1	2	2	3	3	4	4	5
827	751	756	761	766	772	777	782	787	793	798	1	1	2	2	3	3	4	4	5
828	803	808	814	819	824	829	834	840	845	850	1	1	2	2	3	3	4	4	5
829	855	861	866	871	876	882	887	892	897	903	1	1	2	2	3	3	4	4	5
830	908	913	918	924	929	934	939	944	950	955	1	1	2	2	3	3	4	4	5
831	960	965	971	976	981	986	991	997	*002*	*007*	1	1	2	2	3	3	4	4	5
832	92012	018	023	028	033	038	044	049	054	059	1	1	2	2	3	3	4	4	5
833	065	070	075	080	085	091	096	101	106	111	1	1	2	2	3	3	4	4	5
834	117	122	127	132	137	143	148	153	158	163	1	1	2	2	3	3	4	4	5
835	169	174	179	184	189	195	200	205	210	215	1	1	2	2	3	3	4	4	5
836	221	226	231	236	241	247	252	257	262	267	1	1	2	2	3	3	4	4	5
837	273	278	283	288	293	298	304	309	314	319	1	1	2	2	3	3	4	4	5
838	324	330	335	340	345	350	355	361	366	371	1	1	2	2	3	3	4	4	5
839	376	381	387	392	397	402	407	412	418	423	1	1	2	2	3	3	4	4	5
840	428	433	438	443	449	454	459	464	469	474	1	1	2	2	3	3	4	4	5
841	480	485	490	495	500	505	511	516	521	526	1	1	2	2	3	3	4	4	5
842	531	536	542	547	552	557	562	567	572	578	1	1	2	2	3	3	4	4	5
843	583	588	593	598	603	609	614	619	624	629	1	1	2	2	3	3	4	4	5
844	634	639	645	650	655	660	665	670	675	681	1	1	2	2	3	3	4	4	5
845	686	691	696	701	706	711	716	722	727	732	1	1	2	2	3	3	4	4	5
845	737	742	747	752	758	763	768	773	778	783	1	1	2	2	3	3	4	4	5
847	788	793	799	804	809	814	819	824	829	834	1	1	2	2	3	3	4	4	5
848	840	845	850	855	860	865	870	875	881	886	1	1	2	2	3	3	4	4	5
849	891	896	901	906	911	916	921	927	932	937	1	1	2	2	3	3	4	4	5
850	942	947	952	957	962	967	973	978	983	988	1	1	2	2	3	3	4	4	5
851	993	998	*003*	*008*	*013*	*018*	*024*	*029*	*034*	*039*	1	1	2	2	3	3	4	4	5
852	93044	049	054	059	064	069	075	080	085	090	1	1	2	2	3	3	4	4	5
853	095	100	105	110	115	120	125	131	136	141	1	1	2	2	3	3	4	4	5
854	146	151	156	161	166	171	176	181	186	192	0	1	2	2	3	3	4	4	5
855	197	202	207	212	217	222	227	232	237	242	0	1	2	2	3	3	4	4	5
856	247	252	258	263	268	273	278	283	288	293	0	1	2	2	3	3	4	4	5
857	298	303	308	313	318	323	328	334	339	344	0	1	2	2	3	3	4	4	5
858	349	354	359	364	369	374	379	384	389	394	0	1	2	2	3	3	4	4	5
859	399	404	409	414	420	425	430	435	440	445	0	1	2	2	3	3	4	4	5

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
860	93450	455	460	465	470	475	480	485	490	495	0	1	2	2	3	3	4	4	5
861		500	505	510	515	520	526	531	536	541	546	0	1	2	2	3	3	4	4	5
862		551	556	561	566	571	576	581	586	591	596	0	1	2	2	3	3	4	4	5
863		601	606	611	616	621	626	631	636	641	646	0	1	2	2	3	3	4	4	5
864		651	656	661	666	671	676	682	687	692	697	0	1	2	2	3	3	4	4	5
865		702	707	712	717	722	727	732	737	742	747	0	1	2	2	3	3	4	4	5
866		752	757	762	767	772	777	782	787	792	797	0	1	2	2	2	3	4	4	5
867		802	807	812	817	822	827	832	837	842	847	0	1	2	2	2	3	4	4	4
868		852	857	862	867	872	877	882	887	892	897	0	1	2	2	3	3	4	4	4
869		902	907	912	917	922	927	932	937	942	947	0	1	2	2	2	3	3	4	4
870		952	957	962	967	972	977	982	987	992	997	0	1	1	2	2	3	3	4	4
871	94002	007	012	017	022	027	032	037	042	047	0	1	1	2	2	3	3	4	4
872		052	057	062	067	072	077	082	086	091	096	0	1	1	2	2	3	3	4	4
873		101	106	111	116	121	126	131	136	141	146	0	1	1	2	2	3	3	4	4
874		151	156	161	166	171	176	181	186	191	196	0	1	1	2	2	3	3	4	4
875		201	206	211	216	221	226	231	236	240	245	0	1	1	2	2	3	3	4	4
876		250	255	260	265	270	275	280	285	290	295	0	1	1	2	2	3	3	4	4
877		300	305	310	315	320	325	330	335	340	344	0	1	1	2	2	3	3	4	4
878		349	354	359	364	369	374	379	384	389	394	0	1	1	2	2	3	3	4	4
879		399	404	409	414	419	424	429	433	438	443	0	1	1	2	2	3	3	4	4
880		448	453	458	463	468	473	478	483	488	493	0	1	1	2	2	3	3	4	4
881		498	503	507	512	517	522	527	532	537	542	0	1	1	2	2	3	3	4	4
882		547	552	557	562	567	571	576	581	586	591	0	1	1	2	2	3	3	4	4
883		596	601	606	611	616	621	626	630	635	640	0	1	1	2	2	3	3	4	4
884		645	650	655	660	665	670	675	680	685	689	0	1	1	2	2	3	3	4	4
885		694	699	704	709	714	719	724	729	734	738	0	1	1	2	2	3	3	4	4
886		743	748	753	758	763	768	773	778	783	787	0	1	1	2	2	3	3	4	4
887		792	797	802	807	812	817	822	827	832	836	0	1	1	2	2	3	3	4	4
888		841	846	851	856	861	866	871	876	880	885	0	1	1	2	2	3	3	4	4
889		890	895	900	905	910	915	919	924	929	934	0	1	1	2	2	3	3	4	4
890		939	944	949	954	959	963	968	973	978	983	0	1	1	2	2	3	3	4	4
891		988	993	998	*002*	*007*	*012*	*017*	*022*	*027*	*032*	0	1	1	2	2	3	3	4	4
892	95036	041	046	051	056	061	066	071	075	080	0	1	1	2	2	3	3	4	4
893		085	090	095	100	105	109	114	119	124	129	0	1	1	2	2	3	3	4	4
894		134	139	143	148	153	158	163	168	173	177	0	1	1	2	2	3	3	4	4
895		182	187	192	197	202	207	211	216	221	226	0	1	1	2	2	3	3	4	4
896		231	236	240	245	250	255	260	265	270	274	0	1	1	2	2	3	3	4	4
897		279	284	289	294	299	303	308	313	318	323	0	1	1	2	2	3	3	4	4
898		328	332	337	342	347	352	357	361	366	371	0	1	1	2	2	3	3	4	4
899		376	381	386	390	395	400	405	410	415	419	0	1	1	2	2	3	3	4	4

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
900	95424	429	434	439	444	448	453	458	463	468	0	1	1	2	2	3	3	4	4
901	472	477	482	487	492	497	501	506	511	516	0	1	1	2	2	3	3	4	4
902	521	525	530	535	540	545	550	554	559	564	0	1	1	2	2	3	3	4	4
903	569	574	578	583	588	593	598	602	607	612	0	1	1	2	2	3	3	4	4
904	617	622	626	631	636	641	646	650	655	660	0	1	1	2	2	3	3	4	4
905	665	670	674	679	684	689	694	698	703	708	0	1	1	2	2	3	3	4	4
906	713	718	722	727	732	737	742	746	751	756	0	1	1	2	2	3	3	4	4
907	761	766	770	775	780	785	789	794	799	804	0	1	1	2	2	3	3	4	4
908	809	813	818	823	828	832	837	842	847	852	0	1	1	2	2	3	3	4	4
909	856	861	866	871	875	880	885	890	895	899	0	1	1	2	2	3	3	4	4
910	904	909	914	918	923	928	933	938	942	947	0	1	1	2	2	3	3	4	4
911	952	957	961	966	971	976	980	985	990	995	0	1	1	2	2	3	3	4	4
912	999	*004*	*009*	*014*	*019*	*023*	*028*	*033*	*038*	*042*	0	1	1	2	2	3	3	4	4
913	96047	052	057	061	066	071	076	080	085	090	0	1	1	2	2	3	3	4	4
914	095	099	104	109	114	118	123	128	133	137	0	1	1	2	2	3	3	4	4
915	142	147	152	156	161	166	171	175	180	185	0	1	1	2	2	3	3	4	4
916	190	194	199	204	209	213	218	223	227	232	0	1	1	2	2	3	3	4	4
917	237	242	246	251	256	261	265	270	275	280	0	1	1	2	2	3	3	4	4
918	284	289	294	298	303	308	313	317	322	327	0	1	1	2	2	3	3	4	4
919	332	336	341	346	350	355	360	365	369	374	0	1	1	2	2	3	3	4	4
920	379	384	388	393	398	402	407	412	417	421	0	1	1	2	2	3	3	4	4
921	426	431	435	440	445	450	454	459	464	468	0	1	1	2	2	3	3	4	4
922	473	478	483	487	492	497	501	506	511	515	0	1	1	2	2	3	3	4	4
923	520	525	530	534	539	544	548	553	558	562	0	1	1	2	2	3	3	4	4
924	567	572	577	581	586	591	595	600	605	609	0	1	1	2	2	3	3	4	4
925	614	619	624	628	633	638	642	647	652	656	0	1	1	2	2	3	3	4	4
926	661	666	670	675	680	685	689	694	699	703	0	1	1	2	2	3	3	4	4
927	708	713	717	722	727	731	736	741	745	750	0	1	1	2	2	3	3	4	4
928	755	759	764	769	774	778	783	788	792	797	0	1	1	2	2	3	3	4	4
929	802	806	811	816	820	825	830	834	839	844	0	1	1	2	2	3	3	4	4
930	848	853	858	862	867	872	876	881	886	890	0	1	1	2	2	3	3	4	4
931	895	900	904	909	914	918	923	928	932	937	0	1	1	2	2	3	3	4	4
932	942	946	951	956	960	965	970	974	979	984	0	1	1	2	2	3	3	4	4
933	988	993	997	*002*	*007*	*011*	*016*	*021*	*025*	*030*	0	1	1	2	2	3	3	4	4
934	97035	039	044	049	053	058	063	067	072	077	0	1	1	2	2	3	3	4	4
935	081	086	090	095	100	104	109	114	118	123	0	1	1	2	2	3	3	4	4
936	128	132	137	142	146	151	155	160	165	169	0	1	1	2	2	3	3	4	4
937	174	179	183	188	192	197	202	206	211	216	0	1	1	2	2	3	3	4	4
938	220	225	230	234	239	243	248	253	257	262	0	1	1	2	2	3	3	4	4
939	267	271	276	280	285	290	294	299	304	308	0	1	1	2	2	3	3	4	4

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
940	97313	317	322	327	331	336	340	345	350	354	0	1	1	2	2	3	3	4	4
941	359	364	368	373	377	382	387	391	396	400	0	1	1	2	2	3	3	4	4
942	405	410	414	419	424	428	433	437	442	447	0	1	1	2	2	3	3	4	4
943	451	456	460	465	470	474	479	483	488	493	0	1	1	2	2	3	3	4	4
944	497	502	506	511	516	520	525	529	534	539	0	1	1	2	2	3	3	4	4
945	543	548	552	557	562	566	571	575	580	585	0	1	1	2	2	3	3	4	4
946	589	594	598	603	607	612	617	621	626	630	0	1	1	2	2	3	3	4	4
947	635	640	644	649	653	658	663	667	672	676	0	1	1	2	2	3	3	4	4
948	681	685	690	695	699	704	708	713	717	722	0	1	1	2	2	3	3	4	4
949	727	731	736	740	745	750	754	759	763	768	0	1	1	2	2	3	3	4	4
950	772	777	782	786	791	795	800	804	809	813	0	1	1	2	2	3	3	4	4
951	818	823	827	832	836	841	845	850	855	859	0	1	1	2	2	3	3	4	4
952	864	868	873	877	882	886	891	896	900	905	0	1	1	2	2	3	3	4	4
953	909	914	918	923	928	932	937	941	946	950	0	1	1	2	2	3	3	4	4
954	955	959	964	968	973	978	982	987	991	996	0	1	1	2	2	3	3	4	4
955	98000	005	009	014	019	023	028	032	037	041	0	1	1	2	2	3	3	4	4
956	046	050	055	059	064	068	073	078	082	087	0	1	1	2	2	3	3	4	4
957	091	096	100	105	109	114	118	123	127	132	0	1	1	2	2	3	3	4	4
958	137	141	146	150	155	159	164	168	173	177	0	1	1	2	2	3	3	4	4
959	182	186	191	195	200	204	209	214	218	223	0	1	1	2	2	3	3	4	4
960	227	232	236	241	245	250	254	259	263	268	0	1	1	2	2	3	3	4	4
961	272	277	281	286	290	295	299	304	308	313	0	1	1	2	2	3	3	4	4
962	318	322	327	331	336	340	345	349	354	358	0	1	1	2	2	3	3	4	4
963	363	367	372	376	381	385	390	394	399	403	0	1	1	2	2	3	3	4	4
964	408	412	417	421	426	430	435	439	444	448	0	1	1	2	2	3	3	4	4
965	453	457	462	466	471	475	480	484	489	493	0	1	1	2	2	3	3	4	4
966	498	502	507	511	516	520	525	529	534	538	0	1	1	2	2	3	3	4	4
967	543	547	552	556	561	565	570	574	579	583	0	1	1	2	2	3	3	4	4
968	588	592	597	601	605	610	614	619	623	628	0	1	1	2	2	3	3	4	4
969	632	637	641	646	650	655	659	664	668	673	0	1	1	2	2	3	3	4	4
970	677	682	686	691	695	700	704	709	713	717	0	1	1	2	2	3	3	4	4
971	722	726	731	735	740	744	749	753	758	762	0	1	1	2	2	3	3	4	4
972	767	771	776	780	784	789	793	798	802	807	0	1	1	2	2	3	3	4	4
973	811	816	820	825	829	834	838	843	847	851	0	1	1	2	2	3	3	4	4
974	856	860	865	869	874	878	883	887	892	896	0	1	1	2	2	3	3	4	4
975	900	905	909	914	918	923	927	932	936	941	0	1	1	2	2	3	3	4	4
976	945	949	954	958	963	967	972	976	981	985	0	1	1	2	2	3	3	4	4
977	989	994	998	*003*	007	*012*	*016*	*021*	*025*	*029*	0	1	1	2	2	3	3	4	4
978	99034	038	043	047	052	056	061	065	069	074	0	1	1	2	2	3	3	4	4
979	078	083	087	*092*	096	100	105	109	114	118	0	1	1	2	2	3	3	4	4

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
980	99123	127	131	136	140	145	149	154	158	162	0	1	1	2	2	3	3	4	4
981	167	171	176	180	185	189	193	198	202	207	0	1	1	2	2	3	3	4	4
982	211	216	220	224	229	233	238	242	247	251	0	1	1	2	2	3	3	4	4
983	255	260	264	269	273	277	282	286	291	295	0	1	1	2	2	3	3	4	4
984	300	304	308	313	317	322	326	330	335	339	0	1	1	2	2	3	3	4	4
985	344	348	352	357	361	366	370	374	379	383	0	1	1	2	2	3	3	4	4
986	388	392	396	401	405	410	414	419	423	427	0	1	1	2	2	3	3	4	4
987	432	436	441	445	449	454	458	463	467	471	0	1	1	2	2	3	3	4	4
988	476	480	484	489	493	498	502	506	511	515	0	1	1	2	2	3	3	4	4
989	520	524	528	533	537	542	546	550	555	559	0	1	1	2	2	3	3	4	4
990	564	568	572	577	581	585	590	594	599	603	0	1	1	2	2	3	3	4	4
991	607	612	616	621	625	629	634	638	642	647	0	1	1	2	2	3	3	4	4
992	651	656	660	664	669	673	677	682	686	691	0	1	1	2	2	3	3	4	4
993	695	699	704	708	712	717	721	726	730	734	0	1	1	2	2	3	3	3	4
994	739	743	747	752	756	760	765	769	774	778	0	1	1	2	2	3	3	3	4
995	782	787	791	795	800	804	808	813	817	822	0	1	1	2	2	3	3	3	4
996	826	830	835	839	843	848	852	856	861	865	0	1	1	2	2	3	3	3	4
997	870	874	878	883	887	891	896	900	904	909	0	1	1	2	2	3	3	3	4
998	913	917	922	926	930	935	939	944	948	952	0	1	1	2	2	3	3	3	4
999	957	961	965	970	974	978	983	987	991	996	0	1	1	2	2	3	3	3	4

Mathematical Constants and their Logarithms.

Log.

$\pi = 3.14159265 \dots (= 22/7$ for all practical purposes) 0.49715

$180/\pi = 57.296° \doteqdot$ radian in degrees $\overline{1}.75813$

$e = 2.71828$ 0.43429

To convert common to Napierian logarithms, multiply by $\text{Log}_e 10 = 2.302585$, or exponential $(2.302585) = 10.$

Powers of Numbers, Areas, &c.

n	n^2	n^3	$\sqrt{n}$	$\dfrac{1}{n}$	πn	$\dfrac{\pi n^2}{4}$
1	1	1	1.0000	1.000000	3.142	0.7854
2	4	8	1.4142	0.500000	6.283	3.1416
3	9	27	1.7320	0.333333	9.425	7.0686
4	16	64	2.0000	0.250000	12.566	12.566
5	25	125	2.2361	0.200000	15.708	19.635
6	36	216	2.4495	0.166667	18.850	28.274
7	49	343	2.6458	0.142857	21.991	38.486
8	64	512	2.8284	0.125000	25.133	50.265
9	81	729	3.0000	0.111111	28.274	63.617
10	100	1000	3.1623	0.100000	31.416	78.540
11	121	1331	3.3166	0.090909	34.558	95.033
12	144	1728	3.4641	0.083333	37.699	113.10
13	169	2197	3.6056	0.076923	40.841	132.73
14	196	2744	3.7417	0.071429	43.982	153.94
15	225	3375	3.8730	0.066667	47.124	176.72
16	256	4096	4.0000	0.062500	50.265	201.06
17	289	4913	4.1231	0.058824	53.407	226.98
18	324	5832	4.2426	0.055556	56.549	254.47
19	361	6859	4.3589	0.052632	59.690	283.53
20	400	8000	4.4721	0.050000	62.832	314.16
21	441	9261	4.5826	0.047619	65.973	346.36
22	484	10648	4.6904	0.045455	69.115	380.13
23	529	12167	4.7958	0.043478	72.257	415.48
24	576	13824	4.8990	0.041667	75.398	452.39
25	625	15625	5.0000	0.040000	78.540	490.88
26	676	17576	5.0990	0.038462	81.681	530.93
27	729	19683	5.1962	0.037037	84.823	572.56
28	784	21952	5.2915	0.035714	87.965	615.75
29	841	24389	5.3852	0.034483	91.106	660.52
30	900	27000	5.4772	0.033333	94.248	706.86
31	961	29791	5.5678	0.032258	97.389	754.77
32	1024	32768	5.6568	0.031250	100.53	804.25
33	1089	35937	5.7446	0.030303	103.67	855.30
34	1156	39304	5.8310	0.029412	106.81	907.92
35	1225	42875	5.9161	0.028571	109.96	962.12
36	1296	46656	6.0000	0.027778	113.10	1017.88
37	1369	50653	6.0828	0.027027	116.24	1075.21
38	1444	54872	6.1644	0.026316	119.38	1134.11
39	1521	59319	6.2450	0.025641	122.52	1194.59
40	1600	64000	6.3246	0.025000	125.66	1256.64
41	1681	68921	6.4031	0.024390	128.81	1320.25
42	1764	74088	6.4807	0.023810	131.95	1385.44
43	1849	79507	6.5574	0.023256	135.09	1452.20
44	1936	85184	6.6332	0.022727	138.23	1520.53
45	2025	91125	6.7082	0.022222	141.37	1590.43
46	2116	97336	6.7823	0.021739	144.51	1661.90
47	2209	103823	6.8556	0.021277	147.65	1734.94
48	2304	110592	6.9282	0.020833	150.80	1809.56
49	2401	117649	7.0000	0.020408	153.94	1885.74

n	n^2	n^3	$\sqrt{n}$	$\dfrac{1}{n}$	πn	$\dfrac{\pi n^2}{4}$
50	2500	125000	7.0711	0.020000	157.08	1963.50
51	2601	132651	7.1414	0.019608	160.22	2042.82
52	2704	140608	7.2111	0.019231	163.36	2123.72
53	2809	148877	7.2801	0.018868	166.50	2206.19
54	2916	157464	7.3485	0.018519	169.64	2290.22
55	3025	166375	7.4162	0.018182	172.78	2375.83
56	3136	175616	7.4833	0.017857	175.93	2463.01
57	3249	185193	7.5498	0.017544	179.07	2551.76
58	3364	195112	7.6158	0.017241	182.21	2642.08
59	3481	205379	7.6812	0.016949	185.35	2733.97
60	3600	216000	7.7460	0.016667	188.49	2827.44
61	3721	226981	7.8102	0.016393	191.63	2922.47
62	3844	238328	7.8740	0.016129	194.77	3019.07
63	3969	250047	7.9372	0.015873	197.92	3117.25
64	4096	262144	8.0000	0.015625	201.06	3216.99
65	4225	274625	8.0623	0.015385	204.20	3318.31
66	4356	287496	8.1240	0.015152	207.34	3421.20
67	4489	300763	8.1854	0.014925	210.48	3525.66
68	4624	314432	8.2462	0.014706	213.63	3631.69
69	4761	328509	8.3066	0.014493	216.77	3739.29
70	4900	343000	8.3666	0.014286	219.91	3848.46
71	5041	357911	8.4262	0.014085	223.05	3959.20
72	5184	373248	8.4853	0.013889	226.19	4071.51
73	5329	389017	8.5440	0.013699	229.33	4185.39
74	5476	405224	8.6023	0.013514	232.47	4300.85
75	5625	421875	8.6602	0.013333	235.62	4417.87
76	5776	438976	8.7178	0.013158	238.76	4536.47
77	5929	456533	8.7750	0.012987	241.90	4656.63
78	6084	474552	8.8318	0.012821	245.04	4778.37
79	6241	493039	8.8882	0.012658	248.18	4901.68
80	6400	512000	8.9443	0.012500	251.32	5026.56
81	6561	531441	9.0000	0.012346	254.47	5153.01
82	6724	551368	9.0554	0.012195	257.61	5281.03
83	6889	571787	9.1104	0.012048	260.75	5410.62
84	7056	592704	9.1652	0.011905	263.89	5541.78
85	7225	614125	9.2195	0.011765	267.03	5674.50
86	7396	636056	9.2736	0.011628	270.17	5808.81
87	7569	658503	9.3274	0.011494	273.32	5944.69
88	7744	681472	9.3808	0.011364	276.46	6082.13
89	7921	704969	9.4340	0.011236	279.60	6221.13
90	8100	729000	9.4868	0.011111	282.74	6361.74
91	8281	753571	9.5394	0.010989	285.88	6503.89
92	8464	778688	9.5917	0.010870	289.02	6647.62
93	8649	804357	9.6436	0.010753	292.17	6792.92
94	8836	830584	9.6954	0.010638	295.31	6939.78
95	9025	857375	9.7468	0.010526	298.45	7088.23
96	9216	884736	9.7980	0.010417	301.59	7238.24
97	9409	912673	9.8489	0.010309	304.73	7389.83
98	9604	941192	9.8995	0.010204	307.87	7542.98
99	9801	970299	9.9499	0.010101	311.02	7697.68
100	10000	1000000	10.0000	0.010000	314.16	7854.00

Approx. Formulæ: $\sqrt{a^2 \pm b} = a \pm \dfrac{b}{2a}$ and $\sqrt[3]{a^3 \pm b} = a \pm \dfrac{b}{3a^2}$

Natural Sines. Natural Tangents.

	0′	10′	20′	30′	40′	50′		0′	10′	20′	30′	40′	50′
0°	·0000	·0029	·0058	·0087	·0116	·0145		·0000	·0029	·0058	·0087	·0116	·0145
1	·0175	·0204	·0233	·0262	·0291	·0320		·0175	·0204	·0233	·0262	·0291	·0320
2	·0349	·0378	·0407	·0436	·0465	·0494		·0349	·0378	·0407	·0437	·0466	·0495
3	·0523	·0552	·0581	·0610	·0640	·0669		·0524	·0553	·0582	·0612	·0641	·0670
4	·0698	·0727	·0756	·0785	·0814	·0843		·0699	·0729	·0758	·0787	·0816	·0846
5	·0872	·0901	·0929	·0958	·0987	·1016		·0875	·0904	·0934	·0963	·0992	·1022
6	·1045	·1074	·1103	·1132	·1161	·1190		·1051	·1080	·1110	·1139	·1169	·1198
7	·1219	·1248	·1276	·1305	·1334	·1363		·1228	·1257	·1287	·1317	·1346	·1376
8	·1392	·1421	·1449	·1478	·1507	·1536		·1405	·1435	·1465	·1495	·1524	·1554
9	·1564	·1593	·1622	·1650	·1679	·1708		·1584	·1614	·1644	·1673	·1703	·1733
10	·1736	·1765	·1794	·1822	·1851	·1880		·1763	·1793	·1823	·1853	·1883	·1914
11	·1908	·1937	·1965	·1994	·2022	·2051		·1944	·1974	·2004	·2035	·2065	·2095
12	·2079	·2108	·2136	·2164	·2193	·2221		·2126	·2156	·2186	·2217	·2247	·2278
13	·2250	·2278	·2306	·2334	·2363	·2391		·2309	·2339	·2370	·2401	·2432	·2462
14	·2419	·2447	·2476	·2504	·2532	·2560		·2493	·2524	·2555	·2586	·2617	·2648
15	·2588	·2616	·2644	·2672	·2700	·2728		·2679	·2711	·2742	·2773	·2805	·2836
16	·2756	·2784	·2812	·2840	·2868	·2896		·2867	·2899	·2931	·2962	·2994	·3026
17	·2924	·2952	·2979	·3007	·3035	·3062		·3057	·3089	·3121	·3153	·3185	·3217
18	·3090	·3118	·3145	·3173	·3201	·3228		·3249	·3281	·3314	·3346	·3378	·3411
19	·3256	·3283	·3311	·3338	·3365	·3393		·3443	·3476	·3508	·3541	·3574	·3607
20	·3420	·3448	·3475	·3502	·3529	·3557		·3640	·3673	·3706	·3739	·3772	·3805
21	·3584	·3611	·3638	·3665	·3692	·3719		·3839	·3872	·3906	·3939	·3973	·4006
22	·3746	·3773	·3800	·3827	·3854	·3881		·4040	·4074	·4108	·4142	·4176	·4210
23	·3907	·3934	·3961	·3987	·4014	·4041		·4245	·4279	·4314	·4348	·4383	·4417
24	·4067	·4094	·4120	·4147	·4173	·4200		·4452	·4487	·4522	·4557	·4592	·4628
25	·4226	·4253	·4279	·4305	·4331	·4358		·4663	·4699	·4734	·4770	·4806	·4841
26	·4384	·4410	·4436	·4462	·4488	·4514		·4877	·4913	·4950	·4986	·5022	·5059
27	·4540	·4566	·4592	·4617	·4643	·4669		·5095	·5132	·5169	·5206	·5243	·5280
28	·4695	·4720	·4746	·4772	·4797	·4823		·5317	·5354	·5392	·5430	·5467	·5505
29	·4848	·4874	·4899	·4924	·4950	·4975		·5543	·5581	·5619	·5658	·5696	·5735
30	·5000	·5025	·5050	·5075	·5100	·5125		·5774	·5812	·5851	·5890	·5930	·5969
31	·5150	·5175	·5200	·5225	·5250	·5275		·6009	·6048	·6088	·6128	·6168	·6208
32	·5299	·5324	·5348	·5373	·5398	·5422		·6249	·6289	·6330	·6371	·6412	·6453
33	·5446	·5471	·5495	·5519	·5544	·5568		·6494	·6536	·6577	·6619	·6661	·6703
34	·5592	·5616	·5640	·5664	·5688	·5712		·6745	·6787	·6830	·6873	·6916	·6959
35	·5736	·5760	·5783	·5807	·5831	·5854		·7002	·7046	·7089	·7133	·7177	·7221
36	·5878	·5901	·5925	·5948	·5972	·5995		·7265	·7310	·7355	·7400	·7445	·7490
37	·6018	·6041	·6065	·6088	·6111	·6134		·7536	·7581	·7627	·7673	·7720	·7766
38	·6157	·6180	·6202	·6225	·6248	·6271		·7813	·7860	·7907	·7954	·8002	·8050
39	·6293	·6316	·6338	·6361	·6383	·6406		·8098	·8146	·8195	·8243	·8292	·8342
40	·6428	·6450	·6472	·6494	·6517	·6539		·8391	·8441	·8491	·8541	·8591	·8642
41	·6561	·6583	·6604	·6626	·6648	·6670		·8693	·8744	·8796	·8847	·8899	·8952
42	·6691	·6713	·6734	·6756	·6777	·6799		·9004	·9057	·9110	·9163	·9217	·9271
43	·6820	·6841	·6862	·6884	·6905	·6926		·9325	·9380	·9435	·9490	·9545	·9601
44	·6947	·6967	·6988	·7009	·7030	·7050		·9657	·9713	·9770	·9827	·9884	·9942

Natural Sines.

	0′	10′	20′	30′	40′	50′
45°	·7071	·7092	·7112	·7133	·7153	·7173
46	·7193	·7214	·7234	·7254	·7274	·7294
47	·7314	·7383	·7353	·7373	·7392	·7412
48	·7431	·7451	·7470	·7490	·7509	·7528
49	·7547	·7566	·7585	·7604	·7623	·7642
50	·7660	·7679	·7698	·7716	·7735	·7753
51	·7771	·7790	·7808	·7826	·7844	·7862
52	·7880	·7898	·7916	·7934	·7951	·7969
53	·7986	·8004	·8021	·8039	·8056	·8073
54	·8090	·8107	·8124	·8141	·8158	·8175
55	·8192	·8208	·8225	·8241	·8258	·8274
56	·8290	·8307	·8323	·8339	·8355	·8371
57	·8387	·8403	·8418	·8434	·8450	·8465
58	·8480	·8496	·8511	·8526	·8542	·8557
59	·8572	·8587	·8601	·8616	·8631	·8646
60	·8660	·8675	·8689	·8704	·8718	·8732
61	·8746	·8760	·8774	·8788	·8802	·8816
62	·8829	·8843	·8857	·8870	·8884	·8897
63	·8910	·8923	·8936	·8949	·8962	·8975
64	·8988	·9001	·9013	·9026	·9038	·9051
65	·9063	·9075	·9088	·9100	·9112	·9124
66	·9135	·9147	·9159	·9171	·9182	·9194
67	·9205	·9216	·9228	·9239	·9250	·9261
68	·9272	·9283	·9293	·9304	·9315	·9325
69	·9336	·9346	·9356	·9367	·9377	·9387
70	·9397	·9407	·9417	·9426	·9436	·9446
71	·9455	·9465	·9474	·9483	·9492	·9502
72	·9511	·9520	·9528	·9537	·9546	·9555
73	·9563	·9572	·9580	·9588	·9596	·9605
74	·9613	·9621	·9628	·9636	·9644	·9652
75	·9659	·9667	·9674	·9681	·9689	·9696
76	·9703	·9710	·9717	·9724	·9730	·9737
77	·9744	·9750	·9757	·9763	·9769	·9775
78	·9781	·9787	·9793	·9799	·9805	·9811
79	·9816	·9822	·9827	·9833	·9838	·9843
80	·9848	·9853	·9858	·9863	·9868	·9872
81	·9877	·9881	·9886	·9890	·9894	·9899
82	·9903	·9907	·9911	·9914	·9918	·9922
83	·9925	·9929	·9932	·9936	·9939	·9942
84	·9945	·9948	·9951	·9954	·9957	·9959
85	·9962	·9964	·9967	·9969	·9971	·9974
86	·9976	·9978	·9980	·9981	·9983	·9985
87	·9986	·9988	·9989	·9990	·9992	·9993
88	·9994	·9995	·9996	·9997	·9997	·9998
89	·9998	·9999	·9999			

Natural Tangents.

	0′	10′	20′	30′	40′	50′
45°	1·000	1·006	1·012	1·018	1·023	1·029
46	1·036	1·042	1·048	1·054	1·060	1·066
47	1·072	1·079	1·085	1·091	1·098	1·104
48	1·111	1·117	1·124	1·130	1·137	1·144
49	1·150	1·157	1·164	1·171	1·178	1·185
50	1·192	1·199	1·206	1·213	1·220	1·228
51	1·235	1·242	1·250	1·257	1·265	1·272
52	1·280	1·288	1·295	1·303	1·311	1·319
53	1·327	1·335	1·343	1·351	1·360	1·368
54	1·376	1·385	1·393	1·402	1·411	1·419
55	1·428	1·437	1·446	1·455	1·464	1·473
56	1·483	1·492	1·501	1·511	1·520	1·530
57	1·540	1·550	1·560	1·570	1·580	1·590
58	1·600	1·611	1·621	1·632	1·643	1·653
59	1·664	1·675	1·686	1·698	1·709	1·720
60	1·732	1·744	1·756	1·768	1·780	1·792
61	1·804	1·816	1·829	1·842	1·855	1·868
62	1·881	1·894	1·907	1·921	1·935	1·949
63	1·963	1·977	1·991	2·006	2·020	2·035
64	2·050	2·065	2·081	2·096	2·112	2·128
65	2·144	2·161	2·178	2·194	2·211	2·229
66	2·246	2·264	2·282	2·300	2·318	2·337
67	2·356	2·375	2·394	2·414	2·434	2·454
68	2·475	2·496	2·517	2·539	2·560	2·583
69	2·605	2·628	2·651	2·675	2·699	2·723
70	2·747	2·773	2·798	2·824	2·850	2·877
71	2·904	2·932	2·960	2·989	3·018	3·047
72	3·078	3·108	3·140	3·172	3·204	3·237
73	3·271	3·305	3·340	3·376	3·412	3·450
74	3·487	3·526	3·566	3·606	3·647	3·689
75	3·732	3·776	3·821	3·867	3·914	3·962
76	4·011	4·061	4·113	4·165	4·219	4·275
77	4·331	4·390	4·449	4·511	4·574	4·638
78	4·705	4·773	4·843	4·915	4·989	5·066
79	5·145	5·226	5·309	5·396	5·485	5·576
80	5·671	5·769	5·871	5·976	6·084	6·197
81	6·314	6·435	6·561	6·691	6·827	6·968
82	7·115	7·269	7·429	7·596	7·770	7·953
83	8·144	8·345	8·556	8·777	9·010	9·255
84	9·514	9·788	10·08	10·39	10·71	11·06
85	11·43	11·83	12·25	12·71	13·20	13·73
86	14·30	14·92	15·60	16·35	17·17	18·07
87	19·08	20·21	21·47	22·90	24·54	26·43
88	28·64	31·24	34·37	38·19	42·96	49·10
89	57·29	68·75	85·94	114·6	171·9	343·8

Mensuration Formulæ.

Triangle. Area $= \frac{1}{2}$ (base $\times$ height), or $= \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$,
where $s = \frac{1}{2}\,(a + b + c)$.

Parallelogram. Area = base $\times$ height.

Simpson's rule. Area $= \dfrac{l}{3}(A + 4\,B + 2\,C)$,

where l = space between two consecutive ordinates
A = sum of first and last ordinates;
B = sum of the even ordinates;
and C = sum of the odd ordinates.

Circle. Circumference $= 2\,\pi r$.

Area $= \pi r^2$ or $\dfrac{\pi d^2}{4}$

Annular ring. Area $= \pi\,(R^2 - r^2)$.

Ellipse. Area $= \dfrac{\pi}{4}$ (product of axes).

Cylinder.   Surface $= 2\,\pi r h + 2\pi r^2$.
Volume $= \pi r^2 h$.

Prism.   Surface $= 2\,(ab + bc + ca)$
Volume $= abc$.
Diagonal $= \sqrt{a^2 + b^2 + c^2}$.

Sphere.   Surface $= 4\,\pi r^2$.

Volume $= \dfrac{4}{3}\,\pi r^3$.

Cone. Curved surface $= 4\,\pi r \times$ slant height $= \pi r \sqrt{r^2 + h^2}$.

Volume $= \dfrac{\pi}{3}\,r^2 h$.

Frustum of cone. Surface $= \pi\,(R + r) \times$ slant height.

Volume $= \dfrac{\pi h}{3}\,(R^2 + r^2 + R\,r)$.

Pyramid.   Volume $= \frac{1}{3}$ (area of base $\times h$).

Trigonometrical Formulæ.

$$\sin a = \frac{\text{opposite}}{\text{hypotenuse}}; \quad \cos a = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\sin a = \sin (180^\circ - a) = \cos (90^\circ - a)$$

$$\cos (180^\circ - a) = -\cos a.$$

$$\tan a = \frac{\text{opposite}}{\text{adjacent}}$$

In triangle ABC : $\quad \dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}.$

$$\text{Area} = \frac{1}{2}\,bc \sin A$$

Mechanical Constants and their Logarithms.

		Log.
$g = 32 \cdot 2$ ft. per sec.^{2}		1·50786
$= 981$ cm. per sec.^{2}		2·99167

(Actual figures : London, 32·19078; Paris, 32·18255; New York, 32·15945 ft. per sec.^{2})

		Log.
1 lb. weight	$= 4 \cdot 45 \times 10^5$ dynes	5·64836
1 ft.-lb.	$= 1 \cdot 356 \times 10^7$ ergs	7·13226
10^6 dynes	$= 2 \cdot 247$ lb. weight	0·35160
10^8 ergs	$= 7 \cdot 371$ ft.-lb.	0·86753
1 atmosphere	$= 14 \cdot 7$ lb. weight per sq. in.	1·16732
	$= 1 \cdot 014 \times 10^6$ dynes per sq. cm.	6·00604
1 horse-power	$= 33000$ ft.-lb. per min.	4·51851
Mechanical equivalent of heat, $J = 426 \cdot 9$ calories		2·63033
1 B. Th. U.	$= 0 \cdot 252$ Calorie (K)	$\bar{1}$·40140
	$= 252$ calories	2·40140
	$= 778$ ft. lbs.	2·89098
1 (large) Calorie $= 3 \cdot 968$ B. Th. U.		0·59857
1 H.P.	$= 0 \cdot 707$ B. Th. U. per sec.	$\bar{1}$·84942
	$= 0 \cdot 178$ Calorie per sec.	$\bar{1}$·25042
	$= 0 \cdot 746$ Kilowatt.	$\bar{1}$·87274
1 Kilowatt	$= 0 \cdot 949$ B. Th. U. per sec.	$\bar{1}$·97727
	$= 0 \cdot 239$ Calorie per sec.	$\bar{1}$·37840
	$= 738$ ft.-lbs. per sec.	2·86806
	$= 1 \cdot 341$ H.P.	0·12743

Conversion of Pounds per sq. inch to Kilograms per sq. cm.

1 lb. per sq. in. = 0.070310 kgm. per sq. cm.

	0	1	2	3	4	5	6	7	8	9
0		0.0703	0.1406	0.2109	0.2812	0.3516	0.4219	0.4922	0.5625	0.6328
10	0.7031	0.7734	0.8437	0.9140	0.9843	1.0546	1.1250	1.1953	1.2656	1.3359
20	1.4062	1.4765	1.5468	1.6171	1.6874	1.7577	1.8280	1.8984	1.9687	2.0390
30	2.1093	2.1796	2.2499	2.3202	2.3905	2.4608	2.5311	2.6015	2.6718	2.7421
40	2.8124	2.8827	2.9530	3.0233	3.0936	3.1639	2.2342	3.3045	3.3749	3.4452
50	3.5155	3.5858	3.6561	3.7264	3.7967	3.8670	3.9373	4.0076	4.0780	4.1483
60	4.2186	4.2889	4.3592	4.4295	4.4998	4.5701	4.6404	4.7107	4.7810	4.8514
70	4.9217	4.9920	5.0623	5.1326	5.2029	5.2732	5.3435	5.4138	5.4841	5.5545
80	5.6248	5.6951	5.7654	5.8357	5.9060	5.9763	6.0466	6.1169	6.1872	6.2575
90	6.3279	6.3982	6.4685	6.5388	6.6091	6.6794	6.7497	6.8200	6.8903	6.9606
100	7.0310	7.1013	7.1716	7.2419	7.3122	7.3825	7.4528	7.5231	7.5934	7.6637

(In case you are unable to find the data you require, please write :

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